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THE

ORIGIN AND PROGRESS

OF

THE MECHANICAL INVENTIONS

OF

JAMES WATT

ILLUSTRATED BY HIS CORRESPONDENCE WITH HIS FRIENDS
AND THE SPECIFICATIONS OF HIS PATENTS.

53138

BY JAMES PATRICK MUIRHEAD, ESQ., M.A.

184-d-35

IN THREE VOLUMES.

VOL. I.

INTRODUCTORY MEMOIR
AND EXTRACTS FROM CORRESPONDENCE.

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INTRODUCTORY MEMOIR

BY

THE EDITOR.

CHAPTER I.

INTRODUCTION — INVENTORS AND THEIR HISTORY — BIOGRAPHIES OF WATT — NATURE AND SCOPE OF THE PRESENT WORK — MATERIALS FROM WHICH IT HAS BEEN PREPARED — SCREW-PROPELLER FOR STEAM-BOATS SUGGESTED BY MR. WATT IN 1770.

THE fame of James Watt, great as it unquestionably became in the course of his long and honoured life, has increased since his death in a degree that may, perhaps, be termed unprecedented, being coordinate with nothing less than the unlimited development of his own manifold inventions. In the case of illustrious heroes and statesmen, poets, orators, or artists, who have attained the height of their glory in their own time, it often happens that when the excitement of contemporary interest, the influence of power, or the partiality of friendship is removed, the judgment which posterity pronounces on their achievements is not unalloyed by the hesitation of doubt, the coldness of criticism, or the severity of censure. Such, however, has

not been the case with the inventor of the modern steam-engine :—

> " Crescit occulto velut arbor ævo
> " Fama Marcelli :"—

and the renown of so great a promoter of the arts of civilization and the blessings of peace, elastic and expansive as that mighty agent which he first taught men truly to regulate and use, appears, with a steady progression, to have become almost as universally diffused as the all-pervading power of STEAM.

The respect which in all ages and countries has ever been paid to inventors seems, indeed, to rest on something more profound than mere gratitude for the benefits which they have been the means of conferring on mankind; and to imply, if it does not express, a consciousness that by the grand and original conceptions of their minds they approach somewhat more nearly than their fellows to the qualities and pre-eminence of a higher order of being. " The dignity," says Lord Bacon, " of this end of " endowment of man's life with new commodity " appeareth by the estimation that antiquity made " of such as guided thereunto ; for whereas founders " of states, lawgivers, extirpators of tyrants, fathers " of the people, were honoured but with the titles " of demigods, inventors were ever consecrated " among the gods themselves." * And, (to take the instance before us), the multiplication of diver-

* Fragments of Valerius Terminus, on the Interpretation of Nature ; Works of Bacon, by Basil Montagu, 1825, vol. i. p. 266.

sified forms and effects which the living energies of machinery mysteriously call forth from shapeless, inert, and apparently inadequate materials,—the diminution of labour,—the abridgment of time,—the annihilation of distance, which the skilful employment of steam enables us to attain, seem little less than emanations from the awful attribute of creative power; and strikingly exemplify that Divine omnipotence and wisdom, which inspired the genius to conceive, and bestowed the ability to produce them. It is recorded of Mrs. Siddons that when, in the Louvre, in 1814, she beheld the statue of the Apollo Belvidere, she exclaimed "What a great idea it gives us of God, to "think that he has made a human being capable "of fashioning so divine a form!" So when we behold the steam-engine, in all its varied forms and applications, producing its marvellous works with what seems to be almost human intelligence, and even superhuman power,* it is, perhaps, not too much to say that we may feel our conceptions of the ETERNAL WISDOM enlarged by the reflection, that HE formed that mind, which was capable of devising mechanism at once so simple and so sublime.

* "Il faut avouer que voilà la plus merveilleuse de toutes les "machines, et qu'il n'y en a point dont le mécanisme ait plus de "rapport avec celui des animaux. La chaleur est le principe de son "mouvement; il se fait dans ses différens tuyaux une circulation, "comme celle du sang dans les veines, ayant des valvules qui s'ouvrent "et se ferment à propos; elle se nourrit, s'évacue d'elle-même dans "des tems réglés, et tire de son travail tout ce qu'il lui faut pour "subsister."—Belidor, Archit. Hydraul., livre iv. chap. iii. vol. ii. p. 324, 325, ed. 1739.

In proportion to the estimate which men have formed of the importance of the inventor's work is generally the desire they feel to learn the history of its origin and progress. It is observed, in an excellent and practical treatise on the steam-engine, that "the writings Mr. Watt may have left would "be a valuable accession to the stock of know-"ledge possessed by engineers; and it is due to "his fame that they should be made public." * And forty years ago, in applying to Mr. Watt to undertake the labour of himself recording the origin and completion of his principal improvements on the steam-engine, his eminent friend Sir David Brewster had occasion to remark:— "There are many points in the history of an in-"vention which the inventor himself is apt to "overlook as trifling, but in which posterity never "fail to take a deep interest. The progress of the "human mind is never traced with such a lively "interest as through the steps by which it perfects "a great invention; and there is certainly no "invention respecting which this minute informa-"tion will be more eagerly sought after, than in "the case of the steam-engine." †

The whole of the period which has elapsed since the date of that sagacious prediction has witnessed

* "A Treatise on the Steam-engine, Historical, Practical, and De-"scriptive, by John Farey, Engineer;" London, 1827; p. 653. It is impossible too highly to commend the laborious industry with which Mr. Farey has, throughout a long and active life as an engineer, investigated his subject, or to over-estimate the great amount of useful information he has collected in regard to it.

† See vol. ii. p. 344, *infra*.

its progressive and continual fulfilment. Nor can it, we believe, be said with justice, that the public curiosity has yet succeeded in obtaining all the information requisite for its entire satisfaction on the subject to which Sir David Brewster thus referred. The only narrative which Mr. Watt ever published of his own inventions, is that contained in his commentaries on Professor Robison's Dissertations on Steam and Steam-engines, prepared in compliance with the friendly request above referred to. Although deeply interesting, and, of course, of the highest authority, it is at the same time extremely brief; and its author did not profess either to have attempted to render Dr. Robison's work a complete history of the steam-engine, or to have given a *detailed* account of his own numerous improvements on that machine. "The former," he says, "would have been an "undertaking beyond my present powers," (Mr. Watt was at that time upwards of seventy-eight years of age); "and the latter must much have "exceeded the limits of a commentary upon my "friend's work. I have therefore confined myself "to correcting such parts as appeared necessary, "and to adding such matter as he had not any "opportunity of knowing."

The same characteristics, of great brevity, but also of comprehensive accuracy and interest, apply to the biographical sketch which, shortly after his father's death, the late Mr. James Watt of Aston-Hall prepared, at the request of the editor of the seventh edition of the Encyclopædia Britannica,

and which is published in that useful and widely-circulated work.* But there still remained some room for the remark made in the preface to the Life of the late Captain Huddart, (who was not less eminent as a machinist and engineer than as a navigator), that although "the names of Watt, "Rennie, and Huddart have been long known to "the enlightened of every European country," yet "we cannot but regret that the want of a due "estimation of their own importance should seem "to have prevented their making such notes, or "leaving such memoranda as might have afforded "the means of ascertaining the progress of their "discoveries, and of giving a faithful history of "their lives, which now can only be exhibited as "the one is exemplified in the beneficial results "of their labours, and the other is inscribed on the "memories of their contemporaries."

In 1834, the brilliant Eloge of Watt by M. Arago was read before the Institute of France; and, both on that occasion, and when some years afterwards it was given to the world with somewhat greater

* Memoir of the late Captain Joseph Huddart, F.R.S., &c. (by his son). London, 1821, p. vi. James Walker, Esq., so eminent by his own great works of civil-engineering, as well as by his acquaintance with all that has been done in the past history of his profession, has remarked, that "Watt and Huddart were, indeed, kindred spirits. I "have often seen them," he adds, "together; and at the time, and "since, I have often thought that never were two men better paired in "person and bearing as well as in mind." (Address of the President of the Institution of Civil Engineers to the Annual General Meeting, 17th January, 1843.) A fine portrait of Captain Huddart, by Hoppner, is in the possession of Charles Hampden Turner, Esq., of Rook's Nest, the attached friend of both Huddart and Watt.

fullness of detail, it obtained for its illustrious author no less than for its subject the homage of a just and universal admiration. But the space assigned to M. Arago's learned labours having been bounded by the limits of an academical discourse, and having been in part, (with great propriety and advantage), devoted to tracing the history of the use and application of steam in previous ages, scarcely admitted of all that ample illustration which a more extended biography might have contained, as regarded either the personal history of the great engineer, or the development of his numerous inventions. Nor, probably, could this deficiency be considered as fully supplied, when Lord Brougham, in the first series of his interesting Lives of Men of Science, with all that power of language by which his compositions are distinguished, added to our previous information the results of his personal acquaintance with Mr. Watt, who had long been his Lordship's venerated friend.

In regard to one memorable event of Mr. Watt's scientific life,—his discovery, viz. of the Composition of Water,—the want here referred to may be considered as having been compensated by the publication of his correspondence on that particular subject.* And in a letter addressed to the editor of that work, and printed as prefatory to it, the late Mr. James Watt alludes to his having long had in

* "Correspondence of the late James Watt, on his discovery of the "theory of the Composition of Water; with a letter from his son; "edited, with Introductory Remarks and an Appendix, by James "Patrick Muirhead, Esq., F.R.S.E. London, John Murray, 1846."

view the publication of his father's Specifications of Patents, accompanied, perhaps, by some of his other papers. With this view, many of the engravings of machinery contained in the present work were prepared; but, unfortunately, a loss of sight, and the increasing infirmities of age, continued to disable that gentleman from attempting a task for which a full acquaintance with the particulars of his father's life, and a profound and truly filial reverence for his character and works, would no doubt have been excellent qualifications. After suffering for some years a gradual decay of strength, he died in 1848, in the eightieth year of his age, having previously made over to those friends whom he had requested to act as his executors the whole further care of the publication which he had thus done little more than contemplate.

Under these circumstances it was that the editor, "accepting with a melancholy satisfaction the ho- "nour which the death of his friend hath procured "him,"* undertook the task which in these volumes he has attempted to perform with at least industrious zeal; and which, whatever may have been the sacrifice of time which it involved, has been to him a pleasing labour of friendship, affection, and veneration for the memory of his great relative. The accumulation of letters and other papers which came into his possession on the decease of his late friend, presenting as it did a wide field for examination, seemed at first to promise also the

* Captain King's Introduction to Cook's last Voyage, vol. iii. p. 52, ed. 1784.

most ample and complete materials for selection. Indeed it appeared as if the only difficulty would lie in making a thorough perusal, a sufficiently discriminating choice, and a vigorous enough rejection; for from the time of his invention of the copying-machine, in 1779, Mr. Watt's habitual use of that ingenious contrivance had enabled him to ensure the almost unbroken continuity of the duplicate series of his own letters, and the whole of the correspondence of the great engineer inherited by his son was scrupulously preserved.

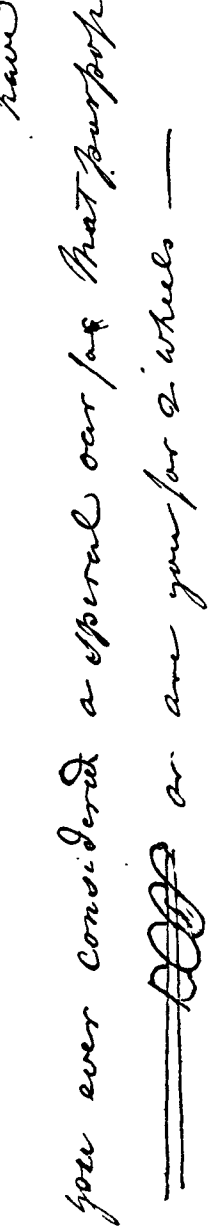
There was, however, a period,—that, viz., previous to 1780,—very full of interest in the history both of the steam-engine and of its great improver, as it comprehended among many other things the grand and fundamental invention of the *separate condenser*, as well as the formation of the partnership at Soho, during which that correspondence, so preserved, was very imperfect; for Mr. Watt being then unprovided with that mechanical aid which he afterwards so skilfully devised for himself, and writing from day to day under the pressure of business of the most multifarious and often fatiguing description, had seldom either the leisure or the inclination to make a copy, or even a note, of the contents of the letters which he hurriedly despatched. The consequence was, that in the important correspondence which for several years about that time took place between Mr. Watt, on the one hand, and Mr. Boulton and their mutual friend, Dr. William Small, on the other, while the letters of both of Mr. Watt's correspondents had

been duly collected and arranged in order, those from himself were wanting.

Those who have been engaged in similar pursuits, and have encountered a similar deficiency, will understand the satisfaction with which the editor discovered in the archives of his brother-in-law, Mr. Boulton, a long series of letters from Mr. Watt, which included those to Dr. W. Small, and apparently comprised, with scarcely a single exception, the whole of those of which he was in search. He has thus been enabled to present in a continuous form, and in the very words of the great inventor himself, what may truly be termed a copious journal of the course of Mr. Watt's life and thoughts, his novel ideas and versatile experiments, while he was engaged in devising and essaying his very earliest and all his other successive improvements on the steam-engine. By nothing less than the magnitude of those improvements, and their importance to mankind, can the curious value of such a record be adequately measured; and its interest is far, indeed, from being diminished by the frequent and full expression which we meet with in its course, of the hopes and fears, the anxieties, distresses, and even despondencies, as well as of the occasional successes and the final triumphs of its modest, but most indefatigable and ingenious author.

As one of the many extraordinary instances of how far his genius and sagacity were in advance of his age, may be mentioned the suggestion,—unknown hitherto to any of his biographers,—which

he makes in one of the letters now referred to,* of no less a scheme than the adoption of the SCREW, instead of paddle-wheels, for propelling steam-boats. His friend, Dr. W. Small, having mentioned the desire which Mr. Boulton and he entertained of moving canal-boats by the steam-engine, (which they at first proposed should be on the high pressure principle):—"*Have you,*" says Mr. Watt in his reply, "*ever "considered* A SPIRAL OAR *for "that purpose, or are you for two "wheels?*" And to make his meaning quite plain, he accompanies his question by this rough sketch of A SCREW PROPELLER: even in the number of turns of the spiral not differing very greatly from such as in our own days, from a wide range of the most careful experiments, have been found to be best fitted for the purpose. The accompanying woodcut gives a faithful facsimile of the remarkable passage in which this idea was started, and which so well deserves to be considered as adding another



* To Dr. W. Small, 30th September, 1770; see No. [85.] vol. ii. p. 8; *infra*.

laurel to those which already adorn the name of Watt.

Unfortunately for the success of the project at that time, Dr. Small in his reply observed,—"I "have tried models of spiral oars, and have found "them all inferior to oars of either of the other "forms; I believe, because a cylinder of water im- "mersed in water can be easily turned round its "axis. This, I dare say, you perfectly know, so "more need not be written. It is "a great misfortune that spiral oars are but indif- "ferent." Dr. S. appears to have understood the proposal as being for two oars, one on either side of the boat; whereas there can be little doubt that Mr. Watt, from using the singular, "a spiral oar," as opposed to *two* wheels, as well as from the very distinct explanatory sketch which he added with his pen, intended his propeller to work at the stern, as a boat is sculled by one oar. Thus, however, did it happen that the project of the screw-propeller, to be worked by his own improved steam-engine, was propounded by James Watt *more than eighty years ago;* that, when propounded, it was, by the discouragement of his friend, abandoned, or at least left *in retentis;* and that only his suggestion of it has remained, to be disentombed at this distance of time, as a fresh instance of his singular ingenuity and foresight, and as one of the greatest curiosities of what may already be termed the traditional history of engineering antiquity!

Throughout the present volumes the principle has been adhered to of making Mr. Watt in great measure his own historian and commentator;

that by full extracts from his letters and memoirs, together with such passages from the writings of others as appeared most suitable, the machine, (to use a metaphor not inappropriate to the subject), which records the details of his life might be made, as far as possible, *self-acting*. Of any such work, it is doubtless impossible to assert with justice that it is absolutely free from errors, whether clerical, typographical, or even, it may be, of a more material nature :—

> "—— quas aut incuria fudit,
> "Aut humana parùm cavit natura."

But to ensure, as far as his efforts might avail, that accuracy which is a primary object of the duties of his office, the editor has united to diligent collation and correction of the press, the careful transcription, by his own hand, of every extract from Mr. Watt's correspondence here printed. In no instance, he trusts, has he permitted his extracts from private correspondence either to violate the sanctity of confidential communication, or to afford just cause for umbrage to any individual now living. For every statement he has made, that seemed of sufficient importance to require it, he has carefully given a reference to his authority. And he feels that his thanks are due to all of those artists of the type and burin who have, in their respective departments, so ably aided his labour, and, as he trusts it will be found, so amply fulfilled his desire of a scrupulous fidelity.

CHAPTER II.

MR WATT'S CHILDHOOD — HIS CALL TO BE A MECHANICAL PHILOSOPHER — PORTRAITS OF NAPIER AND NEWTON — VISIT TO GLASGOW — JOURNEY TO LONDON — PRACTICE OF MATHEMATICAL-INSTRUMENT-MAKING — RETURN TO SCOTLAND.

THE extraction, childhood, and early education of young Watt,—the signs and predictions of his being "no common child,"—the inclination which he ever manifested to observe the problems of the physical world around him, and to reflect on their causes,—and the curious incident of his boyish speculation, in the presence of his aunt Miss Muirheid, on the phenomenon of THE CONDENSATION OF STEAM IN A SEPARATE VESSEL,—have all been so fully described by M. Arago, and others who have followed in his footsteps, as not to require the repetition of their details at our hands.

The ill health which from the boy's earliest years formed an apparent obstacle to his rapid advancement in learning, may have been, in his case as in that of many others, auxiliary in forming habits of persevering study, and a disregard of temptations to the indolent loss or frivolous waste of time

and thought. And to the successful cares of his homely tuition may in great part be traced, not only his habitual industry and practice of many humble virtues, but also that neatness in drawing, handwriting, and other manual occupations, together with skill in the computation of numbers, which he was wont to reckon among his favourite accomplishments,—as well as that strong love of order which presided over every arrangement, and bestowed on his conversation and thoughts, in an extraordinary degree, all the excellences of a lucid method. Of the advantage of such tastes and habits in ordinary life, all men must be in some degree sensible; and it is needless to dilate on their infinite value in a career such as that which he was destined to pursue.

But on the peculiar range of employment to which the main force of his mind was to be directed, he seems, as he grew up, always to have looked with a more than affectionate predilection. The *call*, indeed,—that fixed purpose of soul, declaring itself in action, and leading a man to walk with firmness in a predestined and beloved path,—which made Watt a mechanical philosopher, seems to have been as decided, as that which took Burns from the sheepfolds and raised him to be a fervid bard, or transferred Wilkie from the austerities of a Presbyterian manse to be a glowing and triumphant painter. It was such as calls into life every energy, strengthens into devotion every desire, and creates at once the glory and the happiness of all who, like him,—

———" Fixing hope and aim
" On the humanities of peaceful fame,
" Enter betimes with more than martial fire
" The generous course: aspire, and still aspire;
" Upheld by warnings heeded not too late,
" Stifle the contradictions of their fate,
" And to one purpose cleave, their Being's godlike mate!"*

A circumstance which, whether we regard it as merely a curious coincidence, or as having perhaps in some degree exercised a prophetic direction over the future destiny of young Watt, must be considered as certainly remarkable, is, that among the few articles of household decoration of which the humble mansion of Thomas Watt and his sons could boast, were portraits of Sir Isaac Newton, and of John Napier, the celebrated inventor of logarithms. These paintings, (being, with the exception of some family portraits, which have also been preserved, the only pictorial contents of the house), are not of any very extraordinary pretensions on the score of art; the Newton, in particular, appearing to be a rather indifferent copy of not the best original. But the portrait of Napier is, irrespective of the history of Watt, of high interest, having every appearance of being either an original likeness, or at the least a contemporary copy of a good original, painted with care and fidelity. It is "without the cowl;" therein differing from five out of the six portraits described by Mr. Mark Napier, in the preface to the Memoirs of his great ancestor. And it ap-

* Wordsworth's Stanzas to Liberty. Poetical Works, vol. v. p. 102, ed. 1846.

pears to be the *vera effigies* of the sage, in those latest years of his life when snows of age had fallen on his head, and furrows of ancient thought had been ploughed deep upon his brow;—when not only had his great work, the "Mirifici Ca-"nonis Logarithmorum Descriptio," been for some years made public, but even his "Rhabdologia," the last of all his works which appeared in his lifetime, was either published or, at least, completed in its author's mind; for his left hand is represented as resting on a set of those figured implements of calculation, commonly known in his own country as "Neper's Bones." This, indeed, seems to fix the time at which the likeness was made, at a very late hour in the evening of his life; for the date on the title-page of the printed volume containing the "Rhabdologia," the "Promptuary of Multiplication," and the "Local "Arithmetic," in which the use of the "Bones" is explained, is 1617, and on the 4th of April in that year he died.

Mr. Napier mentions that at Milliken House, in Renfrewshire, so late as the close of the last century, Colonel Milliken Napier, the lineal male representative of Robert, a younger son, and also the literary executor of the author of the Logarithms, was in possession of many private papers of the family; which, "*along with a portrait of the* "*great Napier*, and a Bible with his autograph, "were deposited for safety in a room of the house. "During the owner's absence the house was

" burned to the ground, and the precious relics " perished." * Mr. Napier also mentions that he is unable to trace the history of the other portrait " without the cowl," which is, he says, " a very ori- " ginal-looking half-length," acquired by the late Lord Napier. Possibly one or other of the two " without the cowl " may have been a copy, or *replica* of the portrait said to have perished in the fire at Milliken; that belonging to Thomas Watt at all events inhabited the same county nearly a century before the date of that disaster. But however that may be, the fact of James Watt having been nurtured thus at the feet of those two venerable masters, of his having early and long thus gazed upon the light of their countenances, and imbibed his first acquaintance with their works and fame, as it were, under the sanction of their very presence and eye, is too interesting not to deserve commemoration in the annals of his early days; difficult as it often must be for even the most inquiring minds " to re-ascend in memory to " that which may have given the first impulse to " their entire course of life." †

As among the various occupations of Mr. Watt, sen., was included that of supplying ships with various kinds of nautical apparatus and instru-

* Introduction to Napier's Treatise, " De Arte Logisticâ," printed, under Mr. Mark Napier's able editorship, for the Bannatyne and Maitland Clubs, Edinburgh, 1839, p. iv. See also Mr. Napier's Preface to his " Memoirs of John Napier, of Merchiston," 1834, page v.

† Humboldt's Cosmos, translated by Mrs. Sabine, vol. ii. p. 92, ed. 1849.

ments, there was thus in some sort maintained in his person the tendency towards practical science that had characterised his father and brother, both of whom, in their circumstances of adverse fortune, had become teachers of mathematics; a tendency which, in the subsequent history of his son, was destined to be so illustriously developed. In his later years Mr. Watt of Greenock was unsuccessful in some of the commercial speculations by which he had unwisely sought to improve his means; and it therefore became necessary that both of his sons, at as early an age as possible, should be trained to rely for their future comfort or distinction, and even for their very subsistence, on their own independent exertions.

In witnessing his father's mode of conducting his business, and in assisting him in several of its details, Watt appears to have acquired both good habits of commercial diligence, and some useful rudiments of practical mechanics. Even in his extreme old age there were not wanting occasional recollections of the minor, but secret, mysteries of handicraft in which he had been initiated, when working, "in his shirt-sleeves," in the carpenter's shop;—as when, in his eightieth year, he instructed a certain great bookseller always to have his boxes for books *planed on the inside*; or wrote to Sir Henry Raeburn (2nd March, 1816), "I beg to advise your packer "always *to rub his wood-screws on some candle-grease* "before he screws them in: it will tend much to "his own ease as well as to that of him who un-

"screws them." He soon learned to construct with his own hands several of the articles required by his father in the way of his trade, thus gaining familiarity in working with the different kinds of metal, wood, and other materials, and a serviceable knowledge of their comparative qualities. From the aptitude which he displayed in this kind of work, and in accordance with his own deliberate and earnest choice, it was decided that he should proceed to qualify himself for following the trade of a mathematical-instrument-maker;—a career in which, besides the prospect of turning to good account his habits of industry, his accuracy of eye, and neatness of hand, he doubtless foresaw opportunities such as no other calling within his reach was likely to afford of gratifying his thirst for the knowledge of physical science.

With these views he came to Glasgow in June 1754, being then eighteen years of age, and remained under the roof and care of his maternal relations, the Muirheids, till the month of May in the following year. There is still extant a document which bears amusing testimony to the almost primitive simplicity with which his migration from the paternal home was performed; it is entitled, in the clerkly hand of their youthful possessor, "A list of James Watt's clothes taken "to Glasgow;" and, after certain "silk stockings," "ruffled shirts," and "cut velvet" waistcoats, there follow in it "one working ditto," "one leather apron," "a pair bibels," about a score of

the most needful tools of carpentry, and a quadrant. Of all the latter items,—(with the exception of the "pair bibels," which were, it seems, somehow or other unaccountably left behind!)—it will soon be seen that he made dexterous and successful use.

During his stay at that time in Glasgow, young Watt enjoyed the advantage of being introduced to the notice and acquaintance of several of the most learned Professors in the University, through the instrumentality of his mother's kinsman, Mr. George Muirhead, who had then just exchanged the Professorship of Oriental languages for that of Latin, and was associated with his colleague Professor Moor in scholarlike labours, which have honourably perpetuated his name.*

At that time Black had not as yet been appointed the colleague of men such as Adam Smith and Robert Simson in the ancient University,

* Professors James Moor and George Muirhead were the joint editors of the magnificent Homer, in four volumes folio, which was printed at the University press by the brothers, Robert and Andrew Foulis, in 1756 and 1758; and of which Dr. Harwood says that it is "one of the "most splendid editions of Homer ever delivered to the world, and I am "informed that its accuracy is equal to its magnificence. Since the "publication of the first edition of this work," he adds, "I had occasion "carefully to read through this edition, and I only discovered two trivial "errors." (View of the various editions of the Greek and Roman Classics, with remarks, by Edward Harwood, D.D., 3rd edition. London, 1782.) Professor George Muirhead's own copy of his great work, *on large paper, uncut*, "a fair and everlasting monument" of his diligent scholarship, is now by inheritance in the possession of the Editor of the present more humble publication; who for a further brief record of his learned kinsman's life, may refer to the article on "The "Muirhead Prizes" in "Deeds instituting Prizes in the University of "Glasgow;" 4to. Glasgow, 1850, pp. 201—206.

which the talents of those eminent persons so greatly adorned; and the youthful student has himself recorded that he never attended any course of lectures delivered within the walls, or by the teachers, of the College. But he at once gained the favourable notice of Dr. Dick, who was joint Professor of Natural Philosophy with his father from 1751 to 1757, to whose society the subjects of his pursuits formed an immediate attraction, and of whose abilities, as well as of the kind interest he manifested in his success, Mr. Watt always spoke in terms of the most grateful praise. Dr. Dick having observed the qualifications of his young friend, and being consulted as to his outset in life, strongly recommended his proceeding to London, to acquire better instruction in the art which he designed to practise, than could at that time be gained in Glasgow, or indeed anywhere in Scotland; at the same time furnishing him with a personal introduction which proved very serviceable in obtaining for him the advantage of such tuition.

It being, then, arranged that young Watt should follow this counsel, on the 7th of June, 1755, he set out for the great metropolis, in charge of his connection Mr. Marr,* then the captain of an East Indiaman, who was about to join his ship in the Thames. They travelled, as was common a century ago, on horseback, riding the same horses throughout the journey, which they performed in twelve days, including two of partial or entire

* Mr. Marr's wife was a cousin-german of Mr. Watt.

rest.* Their route was by Coldstream, Newcastle, Durham, York, Doncaster, Newark, and Biggleswade; and the principal note recorded by the young traveller in the new scenes through which he now passed, is a laconic one:—"I like the "country very [well], *but think the people are very* "*sharp.*" It must be added, in explanation of this concise and "canny" conclusion, that nearly one-third of the time occupied on the road was spent in riding through *Yorkshire*;—in fact, the letter which contains it † was written *at York!*

On their arrival in London no time was lost in endeavouring to find a fitting instructor in the mathematical-instrument line,—a task which at first appeared likely to prove one of unexpected difficulty. For the number of masters skilled in that scientific trade was then small, and it was "the custom of London" not to dispense with the regular apprenticeship of seven years on indenture. "I have not yet got a master; we have tried "several; they all make some objection or other," writes the poor lad:—"I find that if any of them "agree with me at all, it will not be for less than "a year; and even at that time [they] will be ex-

* "There was, in the days of which I write, an old-fashioned custom "on the English road, which I suspect is now obsolete, or practised "only by the vulgar. Journeys of length being made on horseback, "and, of course, by brief stages, it was usual always to make a halt on "the Sunday in some town where the traveller might attend Divine "service, and his horse have the benefit of the day of rest, the institu-"tion of which is as humane to our brute labourers as profitable to "ourselves."—Sir W. Scott, Rob Roy, chap. iv., Abbotsford edition, vol. iii. p. 59.

† Mr. Watt to his father, York, 12 June, 1755.

"pecting some money." * Having been nurtured in the observance of rigid frugality, and being most dutifully anxious to avoid all encroachment on his father's means, which seem to have diminished in an inverse ratio to his own necessities, his narrow finances were now a cause of uncomfortable apprehension; and altogether, his early impressions of life in London were very far from being either joyous or encouraging.

But by degrees a little light began to dawn above the dim horizon. "Yesterday," writes Mr. Marr to Mr. Watt, sen., at Greenock,† "your son "began to divert himself in cutting letters and "figures, &c., in the shop of Mr. Neale, watch-"maker, from whom I had the small patent globes. "Mr. Neale is the frankest tradesman of any of the "fraternity I have seen. * * * In the mean-"time I shall endeavour to see him employed at "Mr. Neale's, who inclines to have some of his "work to show." His specimens having been approved of, we find him, by the first week of July, through the exertions of Mr. Short, (a valuable friend whom Dr. Dick's recommendation had procured him), at work on the brass part of Hadley's quadrants, with Mr. John Morgan, mathematical-instrument-maker in Finch Lane, Cornhill;—"a "man," soon afterwards writes his youthful disciple, "of as good a character, both for accuracy "in his business and good morals, as any in his "way in London. Though he works chiefly in the "brass way, yet he can teach me most branches of

* Mr. Watt to his father, London, 1 July, 1755.

† Mr. Marr to Mr. Watt, sen., London, 21 June, 1755.

"the business, such as rules, scales, quadrants, "&c." * "Within the bills of mortality," adds Marr, "he could not have found a man better "recommended for good nature and ingenuity "than Morgan." †

An agreement was soon concluded, with the approbation of Mr. Watt, sen., for his son receiving a year's instruction from Mr. Morgan, for which he was in return to pay twenty guineas, and give his labour for that period in the business. After this, his progress was rapid and steady. By the 5th of August he had made a brass parallel ruler 18 inches long, and a brass scale of the same length, and was about to finish some of Hadley's quadrants; by the 23rd of that month he had done a Hadley's quadrant better than his master's apprentice, "who had been two years "with him;" in October he had begun to make rules, which it was then a most difficult matter to get good, "there being only one man who could "make them perfectly well, and he having lately "taken to other work;" in November he was busy with azimuth compasses; by December, 1755, he "could work tolerably well," and expected that by April he would understand so much of his business as to be able to work for himself, or to be an assistant to his father; when April arrived, he was to make a brass sector, a theodolite, and some other instruments of the better sort: "and then," he writes, "I think I shall be able to get my

* Mr. Watt to his father, London, July 21st, 1755.

† Mr. Marr to Mr. Watt, sen., London, Aug. 6th, 1755.

"bread anywhere, as I am now able to work as "well as most journeymen, though I am not so "quick as many." * And when his year's toil was completed, and the "leafy month of June" had again come round, he announced, with some reasonable pride, that he could now make "a brass "sector with a French joint, which is reckoned as "nice a piece of framing work as is in the trade." †

But all this early expertness was not acquired for nothing; it cost him a constant and hard struggle to reach that step on the upward ladder; and his labours were rendered the more severe by the state of his health, from which he had of late greatly suffered. He had not only, as was his wont, led a life of the most regular and unremitting industry, and spared no exertion by which he might diminish to his father the cost of this part of his education, but his endeavours to attain that end were accompanied by a rigid self-denial on which, however in itself exemplary and laudable, it is almost painful to reflect. Lodging, (it is believed), under the roof of his master, but not receiving from him any of his board, the cost of his food was in all but eight shillings a week; lower than that, he writes, he could not reduce it "*without* "*pinching his belly.*" Even of that pittance, a great portion was earned by himself; for he found that he was able to "win" some money on his own account by rising still earlier than he had to go to his master's work. The bread so bought must have

* Mr. Watt to his father, London, April 20th, 1756.

† Mr. Watt to his father, London, 19 June, 1756.

tasted sweet indeed to his lips; but at night he was thankful enough to get to bed "with his body wea-" ried, and his hand shaking, from ten hours' hard "work." In his letters to his home, while describing the frugality of his way of life, and regretting the charge his living must be to his father, on whom he fervently prays that the blessing of God may rest, he repeatedly adds, that he is striving all he can to improve himself, that he may be the sooner able to assist him, and to ensure his own maintenance.

With such motives to exertion, and such sentiments and habits, it will readily be conceived that he considered his year in London as admitting of no holiday indulgence. So earnestly was he bent on self-improvement in the way of his business, and so entirely were his whole time and strength engaged in the constant exertion which that required, that only on two occasions,—the arrival of the King from abroad, and a proclamation of war,—does the uniformity of his industry appear to have been diversified, even by the sight of such pageants as every metropolis from time to time affords to the eyes of the poorest of its inhabitants. Indeed, so far was he from allowing any occupation of his time in even receiving or giving the news of the day, that the only allusion which his letters of that period contain relative to such subjects is the emphatic and summary conclusion, that "*as for* "*news, there is no believing anything that is said;*"—a maxim which, in other days than his, may still perhaps be deemed not altogether devoid of salutary truth!

An unexpected danger at that time hung over his destiny, which might have cut short, at least for a time, his projects of further improvement in natural science, and postponed *sine die* his return to Glasgow College, with all its interesting consequences. This sword of Damocles was the chance of being impressed as a seaman for the navy. He writes, in the spring of 1756, that he avoids "a "very hot press just now by seldom going out." And on a later day he adds, "they now press any- "body they can get, landsmen as well as seamen, "except it be in the liberties of the City, where "they are obliged to carry them before my Lord "Mayor first; and unless one be either a 'prentice "or a creditable tradesman, there is scarce any "getting off again. And if I was carried before "my Lord Mayor, I durst not avow that I wrought "in the City, it being against their laws for any "unfreeman to work, even as a journeyman, "within the Liberties." *

At the close of his engagement with Mr. Morgan, when he "had no doubt he could have got encou- "ragement from either his master or some other," —after long contending with the badness of his health,—he found himself compelled by "violent "rheumatism," "a gnawing pain in his back," and "weariness all over his body," to seek the benefit which he expected to derive from his native air, and the ride homewards. So, in the end of August 1756, he took leave of London and of Mr. Morgan,

* Mr. Watt to his father, London, March 31, 1756.

(who, dying in 1758, was not destined to witness the future success of his pupil), and to revive his drooping health and spirits, he returned to his own country and friends;—first, however, making a small investment of about twenty guineas in half a hundred additional tools, with "absolute neces-"sary" materials for "a great many more that he "knew he must make himself," together with a copy of "Bion's Construction and Use of Mathe-"matical Instruments,"—a copious and useful treatise on the different branches of his intended trade. This was the first edition of the translation of M. Bion's work, by Edward Stone, an excellent, though self-taught, mathematician, a native of Scotland; it was a great enlargement of the original, and two editions of it were subsequently published in folio, bearing the dates of 1758 and 1759, together with a supplement, from which we learn that the first impression had been soon sold off, and a second long called for by the booksellers and the public. The original treatise in French was a small one in quarto, published at Paris in 1752, and its price was only a few francs.

CHAPTER III.

MR. WATT'S EMPLOYMENT BY THE COLLEGE OF GLASGOW — HIS ESTABLISHMENT WITHIN ITS WALLS AS MATHEMATICAL-INSTRUMENT-MAKER TO THE UNIVERSITY — PROGRESS IN HIS BUSINESS — INTRODUCTION TO DR. BLACK AND TO ROBISON — DR. BLACK'S HISTORY OF THEIR FRIENDSHIP, AND OF MR. WATT'S IMPROVEMENT ON THE STEAM-ENGINE.

An occasion was not long of presenting itself for the advantageous employment of that little stock in trade which we have just described, as well as of the newly-acquired skill of its owner. On the 25th of October, 1756, he writes from Glasgow to his father:—"I would have come down [to Gree-"nock] to-day, but that there are some instruments "that are come from Jamaica that Dr. Dick desired "that I would help to unpack, which are expected "to-day." The instruments here spoken of formed a valuable collection, which had been completed at great cost by the best makers in London, for their late proprietor Mr. Alexander Macfarlane, a merchant, long resident in Jamaica, and a cadet of the ancient feudal house of Macfarlane of that Ilk; who seems, amid his mercantile pursuits, not to have forgotten the motto of his family—"*Astra castra*, "*Numen lumen*;" and who, dying in 1755, bequeathed the contents of his observatory to the

University in which he had received his education. The minute of a University meeting on the 26th of October, bears that "Several "of the instruments from Jamaica having suffered "by the sea-air, especially those made of iron, Mr. "Watt, who is well skilled in what relates to the "cleaning and preserving of them, being accidentally in town, Mr. Moor and Dr. Dick are "appointed to desire him to stay some time in "town to clean them, and put them in the best "order for preserving them from being spoiled." On the 2nd of December the same records bear that "a precept was signed to pay James Watt "five pounds sterling for cleaning and refitting "the instruments lately come from Jamaica;"—this being, in all probability, the first money he had earned on his own account since the termination of his brief apprenticeship.

* The great astronomer Oltmanns, the companion of Humboldt, in mentioning, among various observations from which various latitudes and longitudes in the West Indies were accurately determined, some which Mr. Macfarlane had made, at Port Royal, near Kingston, Jamaica, (Phil. Trans. for 1723, p. 235, and for 1750, p. 523), has said:—"Macfárlane étoit muni d'excellens instruments Anglois, et "très-versé dans la théorie et la pratique de l'astronomie." "Recueil "d'Observations Astronomiques, Voyage de Humboldt et Bonpland," Quatrième Partie, tome ii., p. 589, ed. 1810.

For an account of certain curious lunar observations of another sort, made by the Clan Macfarlane in earlier times, see Sir Walter Scott's note on *Mac-Farlane's boat, or lantern*, in Waverley, chapter xxxviii., where he says, "The clan of Mac-Farlane, occupying the fastnesses of "the western side of Loch Lomond, were great depredators on the Low "Country; and, as their excursions were made usually by night, the "moon was proverbially called their lantern. Their celebrated pibroch of "*Hoggil nam bo*, which is the name of their gathering-tune, intimates "similar practices," &c. (Abbotsford Edition, vol. i. p. 213.)

His next object was to endeavour to establish himself in the way of his trade in the city of Glasgow; but here he was met by obstacles of the same sort as those which in London had first well-nigh excluded him from the brief instruction which he sought, and then might have consigned him, without hope of rescue, to the embraces of the press-gang. Neither being the son of a burgess, nor having served a regular apprenticeship to a *craft*, he was visited, by tradesmen of more arrogant and far more unfounded pretensions than the modest youth whom they persecuted, with a sort of temporal excommunication; and was forbidden to set up even a humble workshop, himself its solitary tenant, within the limits of the burgh. He now signally found the advantage of that academical support which the University uniformly extended to him. By midsummer, 1757, he had received permission to occupy an apartment and open a shop within the precincts of the College, and to use the designation of "Mathematical-instrument-maker to the Uni-"versity;" * and in the autumn of that year, the foundation-stone of an astronomical observatory, to receive the collection of instruments which he had repaired and set up, and to be called the Mac-

* It does not appear that any contemporaneous record has been preserved in the Archives of the University of the date of the workshop having been assigned to him; but on the 27th of November, 1759, directions were given for having "the room above Mr. Watt's work-"shop" repaired. See "Deeds instituting Bursaries, Scholarships, and "other Foundations in the College and University of Glasgow," 1850: 4to., p. 215.

farlane Observatory, was laid, he being then twenty-one years of age. At the same time, however, he had the sorrow and misfortune to lose his able and true friend, Dr. Dick; and the result, in a pecuniary point of view, of this first year of his business, was very far from being a hopeful one.

On the 15th September, 1758, (the year in which his old master, Morgan, died), he thus writes from Glasgow to his father:—"As I have "now had a year's trial here, I am able to form a "judgment of what may be made of this business, "and find that unless it be the Hadley's instru- "ments, there is little to be got by it, as at most "other jobs I am obliged to do the most of them "myself; and as it is impossible for one person to "be expert at everything, they very often cost "me more time than they should do. However, "if there could be a ready sale procured for "Hadley's quadrants, I could do very well, as I "and one lad can finish three in a week easily; "and selling them at 28*s.* 6*d.*, which is vastly "below what they were ever sold at before, I "have 40*s.* clear on the three. So it will be "absolutely necessary that I take a trip to Liver- "pool to look for customers, and hope that upon "the profits of what I shall be able to sell there "I can go to London in the spring, when I make "no doubt of selling more than I can get made; "all which I want your advice on. And if that "does not succeed, I must fall into some other "way of business, as this will not do in its present

"situation." The sale, however, of the profitable Hadley's instruments appears to have increased at home so much, as to have rendered the proposed speculative trading voyage to Liverpool unnecessary.

It was at this time, that the young artificer's earnest devotion to philosophical pursuits, as well as his amiable and virtuous dispositions, gained him the approving notice and enduring friendship of Dr. Black; who, in 1756, was appointed Professor of Anatomy, and in 1757 Professor of the Practice of Medicine, in Glasgow College. It was also in the commencement of the winter of 1758–9 that he made the acquaintance of another able and ardent student, imbued with predilections similar to his own, Mr. John Robison, afterwards, by Dr. Black's recommendation, appointed to succeed Dr. B. as Lecturer on Chemistry in the University of Glasgow; and who subsequently became eminent as Professor of Natural Philosophy in that of Edinburgh. Both of those learned persons, owing to the accidental circumstance of their testimony having been called for on occasion of infringements of Mr. Watt's patents, at a period nearly forty years subsequent to their first meeting at Glasgow, have left interesting narratives of the rise and progress of their intercourse with Mr. Watt, and of the origin of his first and greatest invention; which, as they do honour alike to their authors and their subject, we do not hesitate to place before our readers. That by Dr. Black, which is by much the shorter of the two, has, it is

believed, never hitherto been noticed by any of the biographers of Watt, nor, indeed, does its existence appear to have been known to them; while from Dr. Robison's longer, but highly curious and important narrative, only a very brief extract was published by M. Arago.

History of Mr. Watt's Improvement of the Steam-Engine. By JOSEPH BLACK, M.D.

"I became acquainted with Mr. James Watt in "the year 1757 or 1758, at which time I was Pro- "fessor of Medicine and Lecturer of Chemistry in "the University of Glasgow. About that time Mr. "Watt came to settle in Glasgow as a maker of "mathematical instruments; but being molested "by some of the corporations, who considered him "as an intruder on their privileges, the University "protected him by giving him a shop within their "precincts, and by conferring on him the title of "Mathematical-instrument-maker to the Univer- "sity.

"I soon had occasion to employ him to make "some things which I needed for my experiments, "and found him to be a young man possessing most "uncommon talents for mechanical knowledge and "practice, with an originality, readiness, and co- "piousness of invention, which often surprised and

* The original document is in the hand-writing of Dr. Black. On the envelope in which it is enclosed, Dr. B. has written, "Mr. Watt's "law-suit, 1796–97."

" delighted me in our frequent conversations to-
" gether. I also had many opportunities to know
" that he was as remarkable for the goodness of his
" heart, and the candour and simplicity of his mind,
" as for the acuteness of his genius and understand-
" ing. I therefore contracted with him an intimate
" friendship, which has continued and increased
" ever since that time. I mention these circum-
" stances only to show how it happened that I was
" thoroughly acquainted with the progress of his
" inventions, and with the different objects that
" engaged his attention, while I remained at Glas-
" gow, and, in a great measure, ever since.

" A few years after he was settled at Glasgow
" he was employed by the Professor of Natural
" Philosophy to examine and rectify a small work-
" able model of a steam-engine, which was out of
" order. This turned a part of his thoughts and
" fertile invention to the nature and improvement
" of steam-engines, to the perfection of their ma-
" chinery, and to the different means by which
" their great consumption of fuel might be dimi-
" nished. He soon acquired such a reputation for
" his knowledge on this subject, that he was em-
" ployed to plan and erect several engines in dif-
" ferent places, while at the same time he was
" frequently making new experiments to lessen the
" waste of heat from the external surface of the
" boiler, and from that of the cylinder.

" But after he had been thus employed a con-
" siderable time, he perceived that by far the
" greatest waste of heat proceeded from the waste

" of steam in filling the cylinder with steam. In " filling the cylinder with steam, for every stroke " of the common engine a great part of the steam " is chilled and condensed by the coldness of the " cylinder, before this last is heated enough to " qualify it for being filled with elastic vapour or " perfect steam; he perceived, therefore, that by " preventing this waste of steam, an incomparably " greater saving of heat and fuel would be at- " tained, than by any other contrivance. It was " thus, in the beginning of the year 1765, that the " fortunate thought occurred to him of condensing " the steam by cold in a separate vessel or appara- " tus, between which and the cylinder a commu- " nication was to be opened for that purpose every " time the steam was to be condensed; while the " cylinder itself might be preserved perpetually " hot, no cold water or air being ever admitted " into its cavity.

" This capital improvement flashed on his mind " at once, and filled him with rapture; and he im- " mediately made a hasty trial of it, which satisfied " him of its value, employing for this purpose a " large brass syringe which he borrowed from a " friend.

" His mind became now very much employed " in contriving the machinery by which this im- " provement might be reduced to practice; and he " soon planned it to such a degree, that he thought " he was ready to make an experiment on a large " scale. But here he was stopped by the want of " funds; and he found it necessary to associate

" himself with some person who had money and " spirit for such an undertaking, and to participate " with him the advantages which might be derived " from this invention. He addressed himself to the " late Dr. Roebuck, whose spirit for enterprise and " improvement in arts was very well known, and " the Doctor accordingly received with zeal the op- " portunity offered to him. A small engine was " soon built in one of the offices of Kinneil House, " near Borrowstoness, where various trials were " made, and some difficulties surmounted, so as to " give satisfaction.

" I must add that I was as much upon a footing " of intimate friendship with Dr. Roebuck as with " Mr. Watt. The Doctor, too, had no small degree " of mechanical knowledge and ingenuity; and was " well qualified to perceive and value the talents " of Mr. Watt. He had also much experience of " the use of common steam-engines, which he em- " ployed in working his colliery. He was withal " ardent and sanguine in the pursuit of his under- " takings, and was therefore a fortunate associate " for Mr. Watt. Mr. Watt was a valetudinarian, " more or less, ever since I knew him; and his " mind was liable to be too much depressed by " little cross accidents, or by the necessity of a " greater expense than he had foreseen; whereas " the Doctor was undaunted on such occasions, and " roused Mr. Watt to disregard expense, and to " double his exertions, until the difficulty was over- " come. But Mr. Watt was the sole inventor of " the capital improvement and contrivance above

" mentioned. I remember very well that it cost " me several reasonings and conversations to in- " form the Doctor fully of the nature of steam, of " the great quantity of heat, and, consequently, of " fuel, necessary to produce it, and of the import- " ance, therefore, of preventing the waste of it.

" While thus employed, Mr. Watt's reputation " for knowledge and skill in the engineering line " occasioned his having an offer made him to take " the levels and make the calculations for an in- " tended canal, which employment his circum- " stances induced him readily to accept. This, and " other business of the same kind, filled up the " greater part of his time for several years, and " produced interruptions or delays of his experi- " ments with his new engine. But in the year " 1769, being now completely satisfied of the " practicability of his invention, he got the patent " for it, and in due time gave in his specification. " There was much consultation between him and " his friends about the terms most proper for this " specification. It ended in a general opinion " among them, that he should not attempt to " describe the machinery of the engine, but take " his patent for the above new and most important " invention, or improvement, of making an addi- " tional vessel or apparatus distinct from the great " cylinder, or from that part of it in which the great " piston moves, in which additional vessel or ap- " paratus alone the steam was to be condensed by " cold, in consequence of its being made to pass " from the cylinder into this vessel. The reasons

" for this opinion are sufficiently obvious. The " above invention is the capital improvement; " variations of the machinery and construction " might be made in many different ways, but which " could have little effect in comparison with it; " and had he given the exact description of the " machinery and construction which he had then " planned, it would have limited him to that pre- " cise and particular construction, and left others " at liberty to evade his patent by varying the " construction in points of little moment, though " they adopted his capital improvement.

" This has, in fact, been the device of some of " those persons who have attempted to encroach " on his patent, and rob him of his lawful right. " They made variations of the construction and " machinery, but none of them were able to pro- " duce an engine which approached to his in per- " fection and power, without adopting the above " capital and most important improvement. The " number of ways, however, by which they have " varied the machinery and the construction are " sufficient to show that Mr. Watt's specification " was clear enough to enable an intelligent engi- " neer to take the advantage of his invention for " the improvement of the steam-engine, and even " to do it in many different ways."

CHAPTER IV.

DR. ROBISON'S HISTORY OF HIS ACQUAINTANCE WITH MR. WATT — ACCOUNT OF HIS CHARACTER, ABILITIES, DISPOSITIONS, HABITS, AND PURSUITS — INVENTION OF THE SEPARATE CONDENSER, AND FURTHER IMPROVEMENTS ON THE STEAM-ENGINE — WILCKE'S AIR-PUMP, WITH VACUUM FORMED BY THE CONDENSATION OF STEAM.

SUCH is the concise, but emphatic and comprehensive account given by Dr. Black. We proceed to give the greater portion of that of Dr. Robison, which, entering more into detail, seems more entirely to place us, as it were, in the very presence, and reveal to us the whole course of thought and inquiry, of his inventive companion and friend. It must be remembered that, according to Mr. Watt's own statement, to Robison belongs the honour of having been the first who drew his attention to the subject of steam-engines;—in 1759 even suggesting their application to "the moving "of wheel-carriages," and to other purposes.

Narrative of Mr. Watt's Invention of the Improved Engine. By PROFESSOR ROBISON.*

"My acquaintance with Mr. Watt began in 1758.†

* The original is in the handwriting of Professor R., and is indorsed "Versus Hornblower and Maberly, 1796."

† Mr. Watt, in his "Recollections of his friend Dr. J. Robison,"

" I was then a student in the University of Glas-
" gow, and studying the science which I now
" profess to teach, Natural Philosophy. The Uni-
" versity was then building an astronomical obser-
" vatory. Mr. Watt came to settle in Glasgow
" as a mathematical and philosophical-instrument-
" maker, and was employed to repair and set up a
" very noble collection of instruments bequeathed
" to the University by Mr. Macfarlane of Jamaica,
" a gentleman well known to the scientific world.
" Mr. Watt had apartments and a workshop within
" the College. I had, from my earliest youth, a
" great relish for the natural sciences, and par-
" ticularly for mathematical and mechanical philo-
" sophy. I was eager to be acquainted with the
" practice of astronomical observation, and my
" wishes were much encouraged by the celebrated
" Dr. Simson, Professor of Geometry, Dr. Dick,
" Professor of Natural Philosophy, and Dr. Moor,
" Professor of Greek; — gentlemen eminent for
" their mathematical abilities. Those gentlemen
" brought me with them into Mr. Watt's shop; and
" when he saw me thus patronised, or introduced,
" his natural complaisance made him readily in-
" dulge my curiosity.

" After first feasting my eyes with the view of

written in April 1805, (see vol. ii. pp. 293-299, *infra*), says, " our " acquaintance began in 1756 or 57, when I was employed by the Uni- " versity of Glasgow to repair and put in order some astronomical instru- " ments, bequeathed to the University by Mr. Macfarlane of Jamaica." One of these earlier dates is no doubt the correct one, as Dr. Robison associates Dr. Dick's name with his first acquaintance with Mr. Watt, and Dr. Dick's death, as mentioned above, took place in 1757.

" fine instruments, and prying into everything, I " conversed with Mr. Watt. I saw a workman, and " expected no more; but was surprised to find a " philosopher, as young as myself, and always " ready to instruct me. I had the vanity to think " myself a pretty good proficient in my favourite " study, and was rather mortified at finding Mr. " Watt so much my superior. But his own high " relish for those things made him pleased with " the chat of any person who had the same tastes " with himself, or his innate complaisance made " him indulge my curiosity, and even encourage " my endeavours to form a more intimate acquaint- " ance with him. I lounged much about him, and, " I doubt not, was frequently teazing him. Thus " our acquaintance began.

" It was interrupted in 1759. I left the College " for the navy, where I was a midshipman four " years, and was present in some of the most re- " markable actions of that war.* My health suffered " so much by a seafaring life, that I was obliged to " give it up, much against my inclination, and " return to my academical habits. I was happy to " find Mr. Watt settled in Glasgow, as fond of

* Among the number, the storming of Quebec was perhaps the most conspicuous. On the eve of that victory, the triumph of which was so much embittered by the death of the gallant Wolfe, it happened that Mr. Robison was on duty in the boat in which that general went to visit some posts; and he has recorded that, as they rowed along, Wolfe repeated aloud nearly the whole of Gray's Elegy, and declared that " he would prefer being the author of that poem to the glory of beating " the French to-morrow." See " Biographical Account of the late Pro- " fessor Robison," by Playfair.

" science as ever. Our acquaintance was renewed;
" I believe, with mutual satisfaction, for I had now
" acquired some knowledge. I had lived in the
" closest intimacy with the late Admiral Sir Charles
" Knowles, and had been a good deal employed in
" marine surveys. I had been employed by the
" Admiralty to make the observations for the trial
" of Mr. Harrison's famous time-piece; in short,
" my habits had been such, that I reckoned myself
" more on a par with Mr. Watt, and hoped for a
" closer acquaintance. Nor was I disappointed. I
" found him as good and kind as ever, as keen
" after the acquisition of knowledge, and well dis-
" posed to listen to the information I could give
" him concerning things which had not fallen in
" his own way. But I found him continually strik-
" ing into untrodden paths, where I was always
" obliged to be a follower.

" Our acquaintance at this time became very
" intimate, and I believe neither of us engaged far
" in any train of thought without the other sharing
" in it. I had had the advantage of a more regular
" education: this frequently enabled me to direct
" or confirm Mr. Watt's speculations, and put into
" a systematic form the random suggestions of his
" inquisitive and inventive mind. This kind of
" friendly commerce knit us more together, and
" each of us knew the whole extent of the other's
" reading and knowledge. I was not singular in
" this attachment. All the young lads of our little
" place that were any way remarkable for scientific
" predilection were acquaintances of Mr. Watt;

" and his parlour was a *rendezvous* for all of this de-
" scription. Whenever any puzzle came in the way
" of any of us, we went to Mr. Watt. He needed
" only to be prompted; everything became to him
" the beginning of a new and serious study; and we
" knew that he would not quit it till he had either
" discovered its insignificance, or had made some-
" thing of it. No matter in what line,—languages,
" antiquity, natural history,—nay, poetry, criticism,
" and works of taste; as to anything in the line of
" engineering, whether civil or military, he was at
" home, and a ready instructor. Hardly any pro-
" jects, such as canals, deepening the river, surveys,
" or the like, were undertaken in the neighbour-
" hood without consulting Mr. Watt; and he was
" even importuned to take the charge of some con-
" siderable works of this kind, though they were
" such as he had not the smallest experience in.
" When to this superiority of knowledge, which
" every man confessed in his own line, is added the
" *naïve* simplicity and candour of Mr. Watt's cha-
" racter, it is no wonder that the attachment of his
" acquaintances was strong. I have seen some-
" thing of the world, and am obliged to say that I
" never saw such another instance of general and
" cordial attachment to a person whom all acknow-
" ledged to be their superior. But this superiority
" was concealed under the most amiable candour,
" and liberal allowance of merit to every man. Mr.
" Watt was the first to ascribe to the ingenuity of
" a friend things which were very often nothing
" but his own surmises, followed out and embodied

" by another. I am well entitled to say this, and
" have often experienced it in my own case.

" But the circumstance which made Mr. Watt's
" acquaintance so valuable to me, was the trait of
" character I have already mentioned. Everything
" became to him a subject of new and serious study,
" —everything became science in his hands; and I
" took every opportunity of offering my feeble aid,
" by prosecuting systematically, and with the help
" of mathematical discussion, thoughts which he
" was contented with having suggested or directed.
" I thus shared the fruits of his invention; and with
" gratitude I here acknowledge my obligations to
" him for that strong relish which I thus acquired
" for rational mechanics, and which I have culti-
" vated with great assiduity and pleasure all my life.
" I also shared with Mr. Watt a good deal of that
" subsidiary knowledge, which he acquired as so
" many stepping-stones in his way to some fa-
" vourite objects. He learned the German lan-
" guage in order to peruse Leupold's 'Theatrum
" 'Machinarum:'—so did I, to know what he was
" about. Similar reasons made us both learn Ita-
" lian; and so of other things. And I cannot
" here pass over another circumstance which
" endeared Mr. Watt to us all: he was without
" the smallest wish to appropriate knowledge to
" himself; and one of his greatest delights was
" to set others on the same road to knowledge
" with himself. No man could be more distant
" from the jealous concealment of a tradesman;
" and I am convinced that nothing but the mag-

" nitude of the prospect which his improvement of " the steam-engine held out to him and his family, " could have made Mr. Watt refuse himself the " pleasure of communicating immediately all his " discoveries to his acquaintances. Nay, he could " *not* conceal it; for, besides the frankly imparting " it to Dr. Black, to myself, and two or three more " intimate friends, he disclosed so much of what he " had been doing, that had it been in London or " Birmingham, I am confident that two or three " patents would have been expedited, for bits of his " method, by bustling tradesmen, before he [would " have] thought himself entitled to solicit such a " thing.

* * * *

" I doubt not but all this will be looked upon " by some as mere panegyric. The ignorant are " insensible to the pleasures of science, and have " no notion of the attachments which this may " produce; and the low-bred minds, whose whole " thoughts are full of concealment, rivalship, and " money-making, can hardly conceive a mind that " is not actuated by similar propensities. But I " have a better opinion of those * on whose feelings " and judgment the issue of this cause is to de- " pend. I wish to show these gentlemen what were " my opportunities of seeing the steps by which " Mr. Watt arrived at his final discovery; and I " am not afraid that they will misinterpret the " satisfaction I feel in having this opportunity of

* The special jury, in the cause " Boulton and Watt *versus* Horn- " blower and Maberly."

" expressing my sentiments of attachment to Mr. " Watt. There is, perhaps, but one other person " now alive * who was a witness to every step of " the invention, and I regret exceedingly that his " extreme illness makes it impossible for my friend " to avail himself of his testimony. The thoughts " of doing him an essential service have sup- " ported me in my journey hither, under very " considerable suffering; and when I find that not " only the fortune but the fair name of a most " worthy man is concerned, I think that nothing " less than life could have excused me from the " sound duty of every good citizen,—the support of " eminent talents and worth against the vile as- " persions of low-bred and ignorant pretenders.

"I think it was in the summer of 1764, or, " perhaps, in the spring of that year, that the Pro- " fessor of Natural Philosophy in the University " desired Mr. Watt to repair a pretty model of " Newcomen's steam-engine. This model was, at " first, a fine plaything to Mr. Watt, and to myself, " now a constant visitor at the workshop. But, like " everything which came into his hands, it soon " became an object of most serious study. This " model being an exact copy of a real engine, the " motion of the piston behoved to be the same, " and the strokes to be much more frequent. In " consequence of this, the boiler was unable to " supply more than a few strokes. The boiler " was made to boil more violently. But this, in- " stead of continuing the motion by a more plen-

* Dr. Black.

" tiful supply of steam, stopped the machine " altogether; and we attributed this to the sta- " tical resistance to the entry of the injection, " which came from a height not much exceeding " a foot. The injection-cistern was placed higher, " but without effect. It was long before the true " cause was thought of; and in the meantime " many observations were made on the per- " formance.

" Mr. Watt had learned from Dr. Black some- " what of his late discovery of the latent heat of " fluids and of steams. The Doctor had established " his doctrine by means of incontrovertible experi- " ments in the case of congelation and liquefaction; " but had not yet devised any very simple and " popular experiments for showing the much " greater quantity of heat which is contained in " steam in a latent state. But the great variety of " curious and abstruse phenomena which were " explicable by this branch of the theory made it " a subject of much conversation among the young " gentlemen at college. Mr. Watt was one of the " most zealous partisans of this theory,* and this " little job of the model came opportunely in his " way, and immediately took his whole attention. " He made many curious experiments; and Dr. " Black publicly acknowledges, in his lectures, his

Note in the handwriting of Mr. Watt.—" Dr. Robison is mistaken " in this. I had not attended to Dr. Black's experiment or theory on " latent heat, until I was led to it in the course of experiments upon the " engines, when the fact proved a stumbling-block which the Doctor " assisted me to get over.—J. W."

" obligations to Mr. Watt for the chief experi-
" ments by which he illustrates and supports his
" theory. I had not yet studied chemistry, and
" Mr. Watt was my first instructor. My mind was
" fired with the inexhaustible fund of instruction
" and entertainment which I now saw before me;
" and I was more assiduous in my attendance on
" Mr. Watt's occupations than ever, and studied
" the little model as much as he did. He very
" early saw that an enormous quantity of steam
" was wasted. The great heat acquired in an
" instant by the cylinder, by the admission of a
" few grains of water in the form of steam, was
" an incontestable proof of the great quantity of
" fire contained in it. And as this could come
" only from the coals, Mr. Watt saw at once that
" the chief improvements that the engine was
" susceptible of must consist in contrivances for
" increasing the production, and for diminishing
" its waste. He greatly improved the boiler, by
" increasing the surface to which the fire was
" applied; he made flues through the middle of the
" water; he placed the fire in the middle of the
" water; and made his boiler of wood, as a worse
" conductor of heat than the brick-work which sur-
" rounds common furnaces. He cased the cylinder,
" and all the conducting-pipes, in materials which
" conducted heat very slowly; he even made them
" of wood. After much acquaintance with his
" models, (for he had now made others), he found
" that there was still a prodigious and unavoidable
" waste of steam and fuel, arising from the neces-

" sity of cooling the cylinder very low at every " effective stroke; and he was able to show that " more than three-fourths of the whole steam was " thus condensed and wasted during the ascent of " the piston. (Subsequent experiments, made with " better apparatus, showed him that the waste was " much greater than this.) I had seen all these " contrivances, and many of the experiments, and " had sometimes contributed my mite to lessen the " expensive waste. But this great cause of loss " seemed to be unavoidable.

" At the breaking-up of the College (I think " in 1765), I went to the country. About a fort- " night after this, I came to town, and went to " have a chat with Mr. Watt, and to communicate " to him some observations I had made on Desa- " guliers' and Belidor's account of the steam-engine. " I came into Mr. Watt's parlour without ceremony, " and found him sitting before the fire, having " lying on his knee a little tin cistern, which he " was looking at. I entered into conversation on " what we had been speaking of at last meeting, " —something about steam. All the while, Mr. " Watt kept looking at the fire, and laid down the " cistern at the foot of his chair. At last he " looked at me, and said briskly, 'You need not " '*fash* yourself any more about that, man; I have " 'now made an engine that shall not waste a " 'particle of steam. It shall all be boiling hot; " '—aye, and hot water injected if I please.' So " saying, Mr. Watt looked with complacency at " the little thing at his feet, and, seeing that I

" observed him, he shoved it away under a table " with his foot. I put a question to him about the " nature of his contrivance. He answered me " rather drily. I did not press him to a further " explanation at that time, knowing that I had of- " fended him a few days before by blabbing a pretty " contrivance which he had hit on for turning the " cocks of the engine. I had mentioned this in " presence of an engine-builder, who was going to " erect one for a friend of mine; and this having " come to Mr. Watt's ears, he found fault with it.

" I was very anxious, however, to learn what " Mr. Watt had contrived, but was obliged to go to " the country in the evening. A gentleman who " was going to the same house, said that he would " give me a place in his carriage, and desired me " to wait for him on the walk by the river-side. I " went thither, and found Mr. Alexander Brown, a " very intimate acquaintance of Mr. Watt's, walk- " ing with another gentleman, (Mr. Craig, archi- " tect). Mr. Brown immediately accosted me with, " 'Well, have you seen Jamie Watt?'—'Yes.'— " 'He 'll be in high spirits now with his engine, " 'isn't he?' 'Yes,' said I, 'very fine spirits.' " 'Gad,' says Mr. Brown, 'the condenser's the " 'thing: keep it but cold enough, and you may " 'have a perfect vacuum, whatever be the heat " 'of the cylinder.' The instant he said this, the " whole flashed on my mind at once. I did all I " could to encourage the conversation, but was " much embarrassed. I durst not appear ignorant " of the apparatus, lest Mr. Brown should find

" that he had communicated more than he ought
" to have done. I could only learn that there was
" a vessel called a condenser, which communicated
" with the cylinder, and that this condenser was
" immersed in cold water, and had a pump to
" clear it of the water which was formed in it. I
" also learned that the great difficulty was to make
" the piston tight; and that leather and felt had
" been tried, and were found quite unable to stand
" the heat. I saw that the whole would be per-
" fectly dry, and that Mr. Watt had used steam
" instead of air to press up his piston, which I
" thought, by Mr. Brown's description, was inverted.
" We parted, and I went home, a very silent com-
" panion to the gentleman who had given me a
" seat. Next day, impatient to see the effects of
" the separate condensation, I sent to Paisley and
" got some tin things made there, in completion of
" the notion that I had formed. I tried it as an
" air-pump, by making my steam-vessel communi-
" cate with a tea-kettle, a condenser, and a glass
" receiver. In less than two minutes I rarefied
" the air in a pretty large receiver more than
" twenty times. I could go no farther in this pro-
" cess, because my pump for taking out the air
" from my condenser was too large, and not tight
" enough; but I saw that when applied to the mere
" purpose of taking out the air generated from the
" water, the vacuum might be made almost com-
" plete. I saw, too, (in consequence of a conversa-
" tion the preceding day with Mr. Watt about the
" eduction-pipe in Beighton's engine), that a long

" suck-pipe, or syphon, would take off all the water.
" In short, I had no doubt that Mr. Watt had
" really made a perfect steam-engine.

" I was very unfortunate in two visits I made to
" Glasgow during that summer; Mr. Watt being
" from home, once at Greenock, seeing his father
" who was ill, and the other time on a survey for
" a canal. When I came to town for the winter,
" I found that Mr. Watt was again from home, and
" that he was deeply engaged with his engine.
" His situation in life made it imprudent to engage
" in great expenses, and he was obliged to look
" out for an associate. Most fortunately there was
" in the neighbourhood such a person as he wished,
" —Dr. Roebuck, a gentleman of very uncommon
" knowledge in all the branches of civil engineer-
" ing, familiarly acquainted with the steam-engine,
" of which he employed several on his collieries,
" and deeply interested in this improvement. He
" was also well accustomed to great enterprises, of
" an undaunted spirit, not scared by difficulties,
" nor a niggard of expense. Such a man was
" indispensably necessary to one of Mr. Watt's
" character;—modest, timid, easily frightened by
" rubs and misgivings, and too apt to despond.
" I do not know who pointed him out to Mr. Watt.*
" He was well acquainted with Mr. Watt's talents,
" and admired them. I believe the connection

* Dr. R. has, however, in another passage of his MS., quoted below (See p. lx,) said, "I believe that Dr. Black was the *chief* means of " forming the connection between Mr. Watt and Dr. Roebuck." From Professor Jardine's letter of 1768, it seems not improbable that *he* also had been of service to the associates in that matter. See p. 25, *infra*.

" was very soon formed. Dr. Black and all Mr. " Watt's friends were happy at seeing so fair a " commencement. At this time I had not the " pleasure of being known to Dr. Roebuck.

" I think it was the middle of winter before I " saw Mr. Watt. When we met, he most frankly " told me all his contrivance; and I took care to " receive it all as perfectly new to me, that I " might not commit Mr. Brown. I remember " well, that when he complained of the great " power expended in working pumps sufficiently " large to exhaust a condenser even of moderate " size, (because they must do it at one stroke " against the whole pressure of the atmosphere), I " mentioned the observation that I had formerly " made to him on the eduction-pipe of Beighton's " engine, and the contrivance which I would de- " duce from it for clearing the condenser of water. " Mr. Watt said, 'O man, do you imagine me so " 'dull as not to have thought on that long ago? " 'But I could give you many reasons why it will " 'not answer so well as a pump. I wish I could " 'as quickly get quit of the air as of the water " 'without a pump. I don't despair even of this.' " He now informed me of many curious properties " of steam relative to its heat and elasticity, " explained his methods of condensation, and men- " tioned some remarkable facts relative to this " subject, which pass to this day before the eyes " of everybody, without being noticed or under- " stood by hundreds who call themselves engineers " and builders of steam-engines.

"After this time, my meetings with Mr. Watt "were less frequent. He was much from home, "working with his engine; and I was now obliged "to devote my whole attention to another subject. "Dr. Black, my preceptor in chemistry, was now "removed to Edinburgh; and, by his very un- "merited recommendation, the University of "Glasgow placed me in the chemical chair which "he had just quitted. Frightened by my own good "fortune, I was obliged to strain every nerve to "do some credit to so partial a recommendation; "and I was obliged to relinquish all other occu- "pations of my thoughts. But I had now learned "all the principles of Mr. Watt's invention, though "I had never seen either his engine, or any model "or drawing of it. I knew of his employing steam "in place of the atmosphere to press forward his "piston, although it was long ere I knew the way "in which he introduced it; I thought he simply "admitted it from the surrounding case by the "open mouth of the cylinder; and it was not till "I was in St. Petersburgh that I learned that he "also introduced it, (without a steam-case), by a "pipe. This, however, was a *natural* part of the "leading thought; and, indeed, was practised by "him in his very first experiment.

"In this experiment, (which was made with a "common anatomist's great injection-syringe for a "cylinder), the piston-rod passed through a collar "of leathers in the cover of the cylinder, and the "steam was admitted through another aperture in "the same cover; and it escaped into the con-

" denser by a similar aperture in a cover on the
" other end of the cylinder. Long after this, I
" found that the little apparatus which I saw on
" his knee, and which he shoved under the table
" with his foot, was the condenser in this first
" experiment. I discovered that I had not com-
" prehended the whole contrivance so completely
" as I imagined. But though I was ashamed of
" my ignorance, my vanity would not let me ac-
" knowledge it, and I took circuitous ways of
" learning more exactly the precise state of the
" engine. I was living in Edinburgh during the
" summer of 1767, near Dr. Black, in order to
" prepare myself for my arduous task, and in my
" conversations with Dr. Black I frequently intro-
" duced Watt's steam-engine. I one day asked
" him why Mr. Watt never thought of impelling
" the piston by steam much stronger than common
" steam, mentioning the way in which I would in-
" troduce and manage it. He then corrected me
" in some parts of my proposed construction, and
" described Mr. Watt's with accuracy; and bade
" me reflect on the enormous size and strength
" which must be given to the boiler, and the ex-
" pense of fuel in supplying steam so dense and so
" hot. All this I had thought on already, and
" only wanted to learn what he had just now told
" me. And now I am fully entitled to say, that
" in the summer of 1767 the whole contrivance
" was perfect in Mr. Watt's mind, although he
" had neither executed the double stroke, nor
" that most beautiful contrivance of cutting off the

" steam before the piston reaches the bottom of " the cylinder; a contrivance which in a moment " fits the engine, however great and powerful, to " any the most trifling task, and makes it more " manageable than any other engine whatever that " is not immediately actuated by the hand of man. " Indeed, any person who deserves the name of " engineer must see, and, if he speak from the " conviction of his conscience, must acknowledge, " that the whole contrivance was perfect in Mr. " Watt's mind in his very first trial.

" During the two following winters, notwith- " standing Mr. Watt's frequent absence from Glas- " gow, and my constant occupation with my " chemical lectures, I had many opportunities of " conversing with him, and learned all his diffi- " culties and embarrassments. He struggled long " to condense with sufficient rapidity without in- " jection, and exhibited many beautiful specimens " of ingenuity and fertility of resource. Many " pretty schemes occurred to him for a rotatory " engine. Some of these I am sorry to find that " he has neglected. I am confident of their com- " plete success; and though I agree with him in " thinking that his engine with a double stroke is " superior to them all, I should have been glad " that they had been executed, because they would " have given a most brilliant specimen of his won- " derful ingenuity and of his knowledge; for, " indeed, the management of steam to perfection is " the employment of an accomplished philosopher.

* * * *

"During my residence in Glasgow I was in "habits of continual intimacy with Mr. Watt. "All who knew him know that it is his greatest "pleasure to communicate his knowledge to those "who have a relish for it. I have reason to think "that he never, from any kind of jealousy, con- "cealed anything from me. From the day that "he—I may almost say *we*—began to play with "the College model, I knew almost every step of "his thoughts. He was confined to his business; "I was more at large, and going about the College. "I ransacked the libraries for every book that he "wanted; and every quotation that he met with "made him impatient till he got at the original. "I saw every book that he got by any other "channel besides the public libraries. So I may "safely say that I knew the whole extent of his "reading. Our abode was too far out of the circle "of business for allowing us to be informed of the "numberless projects that are every day born and "buried in this busy country. I can say, with "great confidence, that nothing ever occurred to "Mr. Watt either by reading or information, of "his leading principle, of a steam-vessel per- "petually and universally hot. All the other "contrivances, of separate condenser,—air and "water-pumps,—amalgam, or rosins, or fats for "keeping the piston air-tight,—are but so many "emanations from this first thought; and I will "venture to say they all came into his mind in "succession, and nearly in the order I have stated, "after he said to himself, 'Let me make an en-

"'gine, working by a piston, in which the cylinder
"'shall be continually hot and perfectly dry.'
"I will venture to say that in no book previous
"to that date is there any account or proposal of
"such a thing, if we except some attempts to put
"the steam-vessel of Worcester's or Savery's
"engine in this predicament, by means of a tra-
"velling mass of oil or air, which was to be in-
"terposed between the steam and the water that
"was to be raised. Of these Mr. Watt and I
"had some very imperfect account; but they never
"interested him, because the very nature of the
"operation made it impossible to do anything
"more than approximate to the desired object.

* * * *

"I must say, further, that the thought was
"wholly Mr. Watt's. For this I have every au-
"thority that can be wished for. I am certain
"that when I went out of town in (May, I think,)
"1765, he had not thought of the method of keep-
"ing the cylinder hot; and I am as certain that a
"fortnight after he had completed it and con-
"firmed it by experiment. Dr. Black, the first
"philosophical chemist of his time, and the most
"scrupulous man upon earth, with respect to
"claims of originality, gave this to Mr. Watt in
"the most unqualified terms, the first time I saw
"him after I had learned it from Mr. Brown, and
"long before I saw Mr. Watt and got it more
"distinctly from himself. I believe that Dr. Black
"was the chief means of forming the connection
"between Mr. Watt and Dr. Roebuck; and I

" recollect most distinctly his saying to me, that " Watt would have some difficulty in managing " Dr. Roebuck, who at that time had not become " a complete convert to the doctrine of latent heat. " Accordingly, it was so; and Mr. Watt was " obliged to yield for some time to the Doctor's " confidence in his own great experience. The " Doctor thought to produce the condensation, with " sufficient rapidity and accuracy, by a very ex- " tensive surface; and Mr. Watt knew that it " also required a great quantity of water, or other " matter, to receive the emerging heat. I know " that these differences of opinion retarded the " completion of the engine.

" But Dr. Roebuck had too much judgment not " to see the conclusiveness of the experiments by " which the doctrine of latent heat is established, " and not to yield to their force; and everything " went on at last to their mutual satisfaction. Dr. " Roebuck knew Mr. Watt's talents, and most libe- " rally praised them. His timidity, his disposition " to despond when under unforeseen difficulties, " and his painful anxiety and diffidence in him- " self, were frequently the subjects of friendly " merriment at the Doctor's fireside; and I have " often heard him say, that without his help, and " even his instruction, on many points of the con- " struction, Mr. Watt could never have gone on. " I have even heard him mention some important, " but subordinate, parts of the engine which were " of his contrivance. But I never heard him lay " the smallest claim to the leading thought of a " hot and dry cylinder for the piston to work in,

" and, therefore, a separate condenser. I never " knew him call it 'my engine,' nor 'our engine,' " but uniformly 'Watt's engine,' when he had " occasion to speak of it as distinct from the *old* " or *Newcomen's* engine. I remember Mrs. Roe- " buck saying one evening, 'Jamie is a queer " 'lad, and without the Doctor his invention would " 'have been lost: but Dr. Roebuck won't let it " 'perish.' I mention all these trifling things " because I have often heard gentlemen living in " the neighbourhood of Borrowstoness speak of " this new project as Dr. Roebuck's, in which he " was assisted by one Watt, from Glasgow. One " gentleman in particular, Mr. Graham of Airth, " insisted with me that Dr. Roebuck was the in- " ventor. But one day Mr. Graham came home " from Falkirk, where he had seen Dr. Roebuck, " and engaged him in conversation on the subject. " He told me that he now saw plainly that Mr. " Watt was the sole author, and said that he " would be at some pains to undeceive some gentle- " men of the neighbourhood, who were of the " opposite opinion. This was very natural. Dr. " Roebuck was a gentleman of uncommon know- " ledge in everything of this kind, and consi- " dered as the first judge in all that country of all " such matters; whereas Mr. Watt was an entire " stranger.

* * * *

"I remember also, that in 1774, or 1775,* after

* This date probably was given by Dr. R. in mistake for a later one, as Mr. Watt's Act of Parliament was obtained in May, 1775; after which, though in the same year, it was that he entered into partnership

" my return from Russia, I had some conversation
" with Dr. Roebuck. The Doctor spoke with some
" dissatisfaction of Boulton and Watt. They were
" now, he said, amassing fortunes from a project
" which his misfortunes had obliged him to cede to
" them. They seemed to have forgotten that he
" had suffered all the anxieties attending the infant
" project; he had run all the risk,—and the risk
" had been very great, both from the novelty of
" the thing, and from Mr. Watt's delicate health,
" and his timidity under difficulties;—that without
" his continual encouragement and support it never
" would have succeeded. He had ceded his right
" on very moderate terms, and he had expected
" some remembrance of this. In this disposition to
" repine at an opportunity which he had lost of
" benefiting himself, it would have been most
" natural for Dr. Roebuck to put a high value on
" any part that he had had in the discovery; and I
" listened with some anxiety to hear if he advanced
" any claim of this kind, for I knew that any such
" thing from Dr. Roebuck would be received with
" much deference. But I have the most distinct
" recollection that he made no claim whatever of
" this sort; but, on the contrary, spoke in the
" highest terms of Mr. Watt's ingenuity and in-
" exhaustible resource of invention.*

with Mr. Boulton. It was several years before the manufacture of the improved steam-engine became in the least degree remunerative.

* We understand these remarks of Dr. Robison to have had reference to some stories told by a person of the name of Joseph Hately, who, having come into the employment of Dr. Roebuck some time after Mr. Watt had begun to make his experimental essays at Kinneil, but having failed to give his employer satisfaction, quitted it, or was discharged,

"The duties of my profession call my attention "to a great variety of very interesting objects. "Of all these, my favourite object is practical me- "chanics. I have, therefore, hunted everywhere "for information, and my opportunities have been "considerable. Understanding most of the lan- "guages of Europe, I have looked into almost "every book which treats of such things; and, in "particular, I have searched for every project in "mechanics, description of machines, and schemes "of public works. I can recollect but one trace of "anything like a separate condenser of steam. "This is in a volume of the 'Commentarii de "'Rebus in Medicinâ et Scientiâ Naturali gestis;'

after a service of about eighteen months. He seems to have afterwards, (16 Nov. 1790), taken out a patent for a "Pneumatic fire-engine;" but would not have been noticed here had it not been for a very absurd fable of which he was the author; which was to the effect that the improved engine had been invented not by Mr. Watt, but by Dr. Roebuck. This story he circulated on the eve of Boulton and Watt's litigation with the infringers of their patent rights; the design of it obviously being, by an allegation of prior invention, to "*avoid*" Mr. Watt's patent. Before venturing to promulgate such a creed he had waited,—no doubt wisely, as he thought,—till the Doctor's death, which happened in 1794: and thus he hoped to escape an effectual contradiction. Such folly and audacity, however, were at once exposed, as they deserve always to be; and we have now before us a letter from Dr. R.'s son, Mr. John Roebuck, (to Mr. Watt, 22d Nov. 1796), in which he says, "I never heard my father in the smallest degree claim any merit or "pretend to have any share in inventing or even in improving upon your "engine. On the contrary, he always represented the whole invention "to be yours." Also, one from a gentleman who had been clerk to Dr. R. at the time in question, and continued in strict friendship with him from that period to the time of his death; who expresses his astonishment "that Mr. Hately should pretend to attribute an inven- "tion to Dr. Roebuck, which on every occasion, during a twenty-seven "years' intimate acquaintance with the Doctor, he had avowed to me, "and to others in my hearing, to be wholly yours." (Mr. James Warrock to Mr. Watt, 26th Nov. 1796.)

"I cannot now recollect the volume, and only "remember that it is a late one; (indeed this whole "work is of a date posterior to 1769). In this "volume there is a short account given of an "air-pump by M. Wilcke, of Upsal or Stockholm, "precisely such as I made when I heard of Mr. "Watt's contrivance.* It is mentioned as a thing

* The following is evidently the notice intended to be referred to :—

* * * * *

"3. *Novum antliarum pneumaticarum genus* proponit Jo. CAR. "WILKE. Lect. Phys. Exp. Utitur nota proprietate vaporum aquæ "ebullientis, ita se expandendorum, ut ex eo loco, quem replent, aerem "expellant. Itaque loco cylindri ejus, in quo vulgares antliæ embulum "agitant, vas habet metallicum, in quod, canalis ope, adscendere possunt "vapores aquæ, super carbonibus ebullientis; per aliam aperturam cedit "illis vaporibus aer in vase (vesicam appellat) contentus. Jungitur "autem vesica orbi alicui, cui campana vitrea imponi queat, ut in vul- "garibus antliis, et illæ tres aperturæ vesicæ, qua vapores intrant, qua "aer exit, qua orbi jungitur, pro lubitu valvulis v. c. aut epistomiis "claudi possunt. Ultima igitur hucusque clausa est. Ubi vapores, in "vesicam adscendentes, sat aeris expulerunt, clauditur epistomium, per "quod aer exierat, aqua frigida vesicæ circumfunditur. Ita frigefacti "vapores guttarum forma redeunt, unde adscenderant; et, clauso "epistomio quod, apertum ante, adscensum illis permittebat, jam vesica "magnam partem vacua est. Illo igitur epistomio, quo orbi jungitur, "aperto, in hoc vacuum irruet aer ex campana. Quæ exantlationis "species repeti potest, ut sub campana remaneat pars aeris, quæ initio "sub campana fuerat, centesima tricesima in machina, quacum ten- "tamen instituerat Noster, non omnino, quantum majori cura reddi "posset, perfecta. Vulgares antliæ etiam postea, quae b. NOLLET ad "eas emendandas fecit, aerem circiter 300 vicibus rarefaciunt; (nihil "habet Noster de antlia Cl. Jo. SMEATON, Phil. Trans. vol. xlvii. "Art. 69, qua aer 500, imo 1000 vicibus tenuior reddi adseritur); "itaque haec paulo melius constructa facile illas aequabit, habet vero "hoc præcipui, quod subito aerem evacuet, non, ut vulgares, paulatim; "(vas magnum in antecessum evacuare, et campanæ ita adplicare, ut "aer campanæ subito in illud irruat, docuerunt b. NOLLET et alii). "Ceterum, cum igne et aqua illi opus, usus quibusdam incommodis "junctus est."

"Kongl. Vetenskaps Academiens Handlingar för Aor 1769,"

" which the Reviewers had forgotten in its proper " time, and they say, '*dudum fabricavit.*' I men- " tioned this about a year ago to Dr. Black, when " we were speaking of some curious observations " of M. Wilcke on the cloud which appears in the " receiver of an air-pump when damp air is sud- " denly rarefied. The Doctor told me, that when " he was yet in Glasgow, he had a pupil of the " name of Williams, or Williamson, from the Mine " College in Sweden; that this person was inti- " mately acquainted in Dr. Roebuck's family, and, " he believed, also with Mr. Watt; that he was in " this country almost three years, and fully under- " stood all his theory; and he had no doubt that " Dr. Wilcke owed to him all that he had published " on that subject. He thought it equally probable " that this project of an air-pump had transpired " in some of our conversations, it being a thing " on which we put no value." * *

vol. xxx. &c., *i.e.*, Acta Academiæ Reg. Sc. Suecicæ, anni 1769, vol. xxx. (Trimestre primum), printed in the " Com- " mentarii de Rebus in Scientiâ Naturali et Medicinâ gestis," voluminis xviii. pars I. Lipsiæ. 1772.

Dr. Robison is not quite accurate in saying that the whole of the " Commentarii " are of a date posterior to 1769. The work was published in a series of thirty-seven volumes, commencing in 1752, and ending in 1806; with three volumes of " Supplementa," 1763-96, and three of Indices, 1770-1793. But it is certain that the passage quoted above is of a date several years subsequent to Mr. Watt's invention of the separate condenser; and the circumstances through which it happened that Mr. Wilcke was even so early in possession of the idea of an air-pump, such as that described, are, no doubt, very well explained by Dr. Robison in the text.

CHAPTER V.

MR. WATT'S NARRATIVE OF THE INVENTIONS DESCRIBED IN HIS SPECIFICATION OF 1769, GIVEN IN HIS NOTES ON ROBISON — FURTHER ANECDOTES OF HIS INVENTION OF THE SEPARATE CONDENSER — HIS NARRATIVE ENTITLED "A PLAIN STORY."

THE account given by Mr. Watt himself, in his Notes on Professor Robison's Dissertation on Steam-engines,* is as follows:—

"My attention was first directed, in the year "1759, to the subject of steam-engines, by the late "Dr. Robison, then a student in the University of "Glasgow, and nearly of my own age. He at "that time threw out an idea of applying the "power of the steam-engine to the moving of "wheel-carriages, and to other purposes; but the "scheme was not matured, and was soon aban-"doned on his going abroad.

"About the year 1761, or 1762, I tried some "experiments on the force of steam in a Papin's "digester, and formed a species of steam-engine "by fixing upon it a syringe, one-third of an inch "diameter, with a solid piston, and furnished also "with a cock to admit the steam from the digester, "or shut it off at pleasure, as well as to open a

* Robison's Mechanical Works, edited by Sir David Brewster.—See vol. ii. p. 347, *infra*.

" communication from the inside of the syringe to " the open air, by which the steam contained in " the syringe might escape. When the communi- " cation between the digester and syringe was " opened, the steam entered the syringe, and by " its action upon the piston raised a considerable " weight (15 lbs.) with which it was loaded. When " this was raised as high as was thought proper, " the communication with the digester was shut, " and that with the atmosphere opened; the steam " then made its escape, and the weight descended. " The operations were repeated, and though in " this experiment the cock was turned by hand, it " was easy to see how it could be done by the " machine itself, and to make it work with perfect " regularity. But I soon relinquished the idea of " constructing an engine upon its principle, from " being sensible it would be liable to some of the " objections against Savery's engine, viz., the " danger of bursting the boiler, and the difficulty " of making the joints tight, and also that a great " part of the power of the steam would be lost, be- " cause no vacuum was formed to assist the descent " of the piston. I, however, described this engine " in the fourth article of the specification of my " patent of 1769; and again in the specification of " another patent in the year 1784, together with " a mode of applying it to the moving of wheel- " carriages.

" The attention necessary to the avocations of " business prevented me from then prosecuting the " subject further; but in the winter of 1763–4,

" having occasion to repair a model of Newcomen's
" engine belonging to the Natural Philosophy class
" of the University of Glasgow, my mind was again
" directed to it. At that period my knowledge
" was derived principally from Desaguliers, and
" partly from Belidor. I set about repairing it as
" a mere mechanician; and when that was done, and
" it was set to work, I was surprised to find that its
" boiler could not supply it with steam, though ap-
" parently quite large enough; (the cylinder of the
" model being two inches in diameter, and six inches
" stroke, and the boiler about nine inches diameter).
" By blowing the fire it was made to take a few
" strokes, but required an enormous quantity of
" injection water, though it was very lightly loaded
" by the column of water in the pump. It soon
" occurred that this was caused by the little cylinder
" exposing a greater surface to condense the steam
" than the cylinders of larger engines did in propor-
" tion to their respective contents. It was found
" that by shortening the column of water in the
" pump, the boiler could supply the cylinder with
" steam, and that the engine would work regularly
" with a moderate quantity of injection. It now
" appeared that the cylinder of the model, being
" of brass, would conduct heat much better than
" the cast-iron cylinders of larger engines, (gene-
" rally covered on the inside with a stony crust),
" and that considerable advantage could be gained
" by making the cylinders of some substance that
" would receive and give out heat slowly. Of these,
" wood seemed to be the most likely, provided it

" should prove sufficiently durable. A small engine " was, therefore, constructed, with a cylinder six " inches diameter, and twelve inches stroke, made " of wood, soaked in linseed oil, and baked to " dryness. With this engine many experiments " were made; but it was soon found that the " wooden cylinder was not likely to prove durable, " and that the steam condensed in filling it still " exceeded the proportion of that required for large " engines, according to the statements of Desagu- " liers. It was also found that all attempts to " produce a better exhaustion by throwing in " more injection, caused a disproportionate waste of " steam. On reflection, the cause of this seemed " to be the boiling of water in vacuo at low heats, " a discovery lately made by Dr. Cullen and some " other philosophers, (below 100°, as I was then " informed), and consequently, at greater heats, " the water in the cylinder would produce a steam " which would, in part, resist the pressure of the " atmosphere.

" By experiments which I then tried upon the " heats at which water boils under several pressures " greater than that of the atmosphere, it appeared " that when the heats proceeded in an arithmetical, " the elasticities proceeded in some geometrical " ratio; and by laying down a curve from my " data, I ascertained the particular one near enough " for my purpose. It also appeared, that any " approach to a vacuum could only be obtained by " throwing in large quantities of injection, which " would cool the cylinder so much as to require

" quantities of steam to heat it again, out of pro-
" portion to the power gained by the more perfect
" vacuum; and that the old engineers had acted
" wisely in contenting themselves with loading the
" engine with only six or seven pounds on each
" square inch of the area of the piston. It being
" evident that there was a great error in Dr. De-
" saguliers' calculations of Mr. Beighton's experi-
" ments on the bulk of steam, a Florence flask,
" capable of containing about a pound of water,
" had about one ounce of distilled water put into
" it; a glass tube was fitted into its mouth, and the
" joining made tight by lapping that part of the
" tube with pack-thread, covered with glazier's
" putty. When the flask was set upright, the tube
" reached down near to the surface of the water,
" and in that position the whole was placed in a
" tin reflecting oven before a fire, until the water
" was wholly evaporated, which happened in about
" an hour, and might have been done sooner had
" I not wished the heat not much to exceed that of
" boiling water. As the air in the flask was heavier
" than the steam, the latter ascended to the top, and
" expelled the air through the tube. When the
" water was all evaporated, the oven and flask were
" removed from the fire, and a blast of cold air was
" directed against one side of the flask, to collect
" the condensed steam in one place. When all was
" cold, the tube was removed; the flask and its
" contents were weighed with care; and the flask
" being made hot, it was dried by blowing into it
" by bellows, and when weighed again, was found

" to have lost rather more than four grains, esti-
" mated at $4\frac{1}{3}$ grains. When the flask was filled
" with water, it was found to contain about
" $17\frac{1}{8}$ ounces avoirdupois of that fluid, which gave
" about 1800 for the expansion of water converted
" into steam of the heat of boiling water.

" This experiment was repeated with nearly the
" same result; and in order to ascertain whether
" the flask had been wholly filled with steam, a
" similar quantity of water was for the third time
" evaporated; and, while the flask was still cold,
" it was placed inverted, with its mouth (contracted
" by the tube) immersed in a vessel of water; which
" it sucked in as it cooled, until in the temperature
" of the atmosphere it was filled to within half an
" ounce measure of water. In the contrivance of
" this experiment I was assisted by Dr. Black. In
" Dr. Robison's edition of Dr. Black's Lectures, vol. i.,
" p. 147, the latter hints at some experiments upon
" this subject, as made by *him*; but I have no know-
" ledge of any except those which I made myself.

" In repetitions of this experiment at a later date,
" I simplified the apparatus by omitting the tube
" and laying the flask upon its side in the oven,
" partly closing its mouth by a cork, having a
" notch on one side, and otherwise proceeding as
" has been mentioned.

" I do not consider these experiments as ex-
" tremely accurate, the only scale-beam of a proper
" size which I had then at my command not being
" very sensible, and the bulk of the steam being
" liable to be influenced by the heat to which it is

" exposed, which, in the way described, is not easily " regulated or ascertained; but, from my expe- " rience in actual practice, I esteem the expansion " to be rather more than I have computed.

" A boiler was constructed which showed, by " inspection, the quantity of water evaporated in " any given time, and thereby ascertained the " quantity of steam used in every stroke by the " engine, which I found to be several times the " full of the cylinder. Astonished at the quantity " of water required for the injection, and the great " heat it had acquired from the small quantity of " water in the form of steam which had been used " in filling the cylinder, and thinking I had made " some mistake, the following experiment was " tried:—A glass tube was bent at right angles; " one end was inserted horizontally into the spout " of a tea-kettle, and the other part was immersed " perpendicularly in well-water contained in a " cylindric glass vessel, and steam was made to " pass through it until it ceased to be condensed, " and the water in the glass vessel was become " nearly boiling hot. The water in the glass vessel " was then found to have gained an addition of " about one-sixth part from the condensed steam. " Consequently, water converted into steam can " heat about six times its own weight of well-water " to 212°, or till it can condense no more steam. " Being struck with this remarkable fact, and not " understanding the reason of it, I mentioned it to " my friend Dr. Black, who then explained to me " his doctrine of latent heat, which he had taught

" for some time before this period, (summer 1764) ;
" but having myself been occupied with the pursuits
" of business, if I had heard of it, I had not attended
" to it, when I thus stumbled upon one of the
" material facts by which that beautiful theory is
" supported.

" On reflecting further, I perceived, that in order
" to make the best use of steam, it was necessary,—
" first, that the cylinder should be maintained
" always as hot as the steam which entered it ; and,
" secondly, that when the steam was condensed,
" the water of which it was composed, and the
" injection itself, should be cooled down to 100°, or
" lower, where that was possible. The means of
" accomplishing these points did not immediately
" present themselves ; but early in 1765 it occurred
" to me, that if a communication were opened
" between a cylinder containing steam, and another
" vessel which was exhausted of air and other
" fluids, the steam, as an elastic fluid, would imme-
" diately rush into the empty vessel, and continue
" so to do until it had established an equilibrium ;
" and if that vessel were kept very cool by an
" injection, or otherwise, more steam would con-
" tinue to enter until the whole was condensed.
" But both the vessels being exhausted, or nearly
" so, how were the injection-water, the air which
" would enter with it, and the condensed steam, to
" be got out? This I proposed, in my own mind,
" to perform in two ways. One was, by adapting
" to the second vessel a pipe, reaching downwards
" more than 34 feet, by which the water would

" descend, (a column of that length overbalancing " the atmosphere), and by extracting the air by " means of a pump.

" The second method was by employing a pump, " or pumps, to extract both the air and the water, " which would be applicable in all places, and " essential in those cases where there was no well " or pit.

" This latter method was the one I then pre- " ferred, and is the only one I afterwards continued " to use.

" In Newcomen's engine, the piston is kept tight " by wafer, which could not be applicable in this " new method; as, if any of it entered into a " partially-exhausted and hot cylinder, it would " boil, and prevent the production of a vacuum, and " would also cool the cylinder by its evaporation " during the descent of the piston. I proposed to " remedy this defect by employing wax, tallow, or " other grease, to lubricate and keep the piston " tight. It next occurred to me, that the mouth of " the cylinder being open, the air which entered " to act on the piston would cool the cylinder, and " condense some steam on again filling it. I there- " fore proposed to put an air-tight cover upon the " cylinder, with a hole and stuffing-box for the " piston-rod to slide through, and to admit steam " above the piston to act upon it, instead of the " atmosphere. The piston-rod sliding through a " stuffing-box was new in steam-engines; it was " not necessary in Newcomen's engine, as the " mouth of the cylinder was open, and the piston-

" rod was square and very clumsy. The fitting " the piston-rod to the piston by a cone was an " after-improvement of mine, (about 1774). There " still remained another source of the destruction " of steam, the cooling of the cylinder by the " external air, which would produce an internal " condensation whenever steam entered it, and " which would be repeated every stroke; this I " proposed to remedy by an external cylinder, con- " taining steam, surrounded by another of wood, or " of some other substance which would conduct " heat slowly.

" When once the idea of the separate condensa- " tion was started, all these improvements followed " as corollaries in quick succession, so that in the " course of one or two days the invention was thus " far complete in my mind, and I immediately set " about an experiment to verify it practically. I " took a large brass syringe, $1\frac{3}{4}$ inches diameter " and 10 inches long, made a cover and bottom to " it of tin-plate, with a pipe to convey steam to " both ends of the cylinder from the boiler; another " pipe to convey steam from the upper end to the " condenser,—(for, to save apparatus, I inverted the " cylinder),—I drilled a hole longitudinally through " the axis of the stem of the piston, and fixed a " valve at its lower end, to permit the water which " was produced by the condensed steam on first " filling the cylinder, to issue. The condenser used " upon this occasion consisted of two pipes of " thin tin-plate, ten or twelve inches long, and about " one-sixth inch diameter, standing perpendicular,

" and communicating at top with a short horizontal " pipe of large diameter, having an aperture on " its upper side, which was shut by a valve opening " upwards. These pipes were joined at bottom to " another perpendicular pipe of about an inch " diameter, which served for the air and water- " pump; and both the condensing pipes and the " air-pump were placed in a small cistern filled " with cold water. This construction of the con- " denser was employed from knowing that heat " penetrated thin plates of metal very quickly, and " considering that if no injection was thrown into " an exhausted vessel, there would be only the " water of which the steam had been composed, " and the air which entered with the steam, or " through the leaks, to extract.

" The steam-pipe was adjusted to a small boiler. " When steam was produced, it was admitted into " the cylinder, and soon issued through the perfo- " ration of the rod, and at the valve of the con- " denser. When it was judged that the air was " expelled, the steam-cock was shut, and the air- " pump piston-rod was drawn up, which leaving " the small pipes of the condenser in a state of " vacuum, the steam entered them and was con- " densed. The piston of the cylinder immediately " rose, and lifted a weight of about 18 lbs., which " was hung to the lower end of the piston-rod. " The exhaustion-cock was shut, the steam was " readmitted into the cylinder, and the operation " was repeated; the quantity of steam consumed, " and the weights it could raise, were observed;

" and, excepting the non-application of the steam-
" case and external covering, the invention was
" complete, in so far as regarded the savings of
" steam and fuel. A large model, with an outer
" cylinder and wooden case, was immediately con-
" structed, and the experiments made with it served
" to verify the expectations I had formed, and to
" place the advantage of the invention beyond the
" reach of doubt. It was found convenient after-
" wards to change the pipe-condenser for an empty
" vessel, generally of a cylindrical form, into which
" an injection played, and, in consequence of there
" being more water and air to extract, to enlarge
" the air-pump.

" The change was made, because, in order to
" procure a surface sufficiently extensive to con-
" dense the steam of a large engine, the pipe-
" condenser would require to be very voluminous,
" and because the bad water with which engines
" are frequently supplied, would crust over the thin
" plates, and prevent their conveying the heat
" sufficiently quick. The cylinders were also placed
" with their mouths upwards, and furnished with a
" working-beam, and other apparatus, as was usual
" in the ancient engines,—the inversion of the
" cylinder, or rather of the piston-rod, in the model,
" being only an expedient to try more easily the
" new invention, and being subject to many objec-
" tions in large engines.

" In 1768 I applied for letters patent for my
" 'Methods of Lessening the Consumption of
" 'Steam, and, consequently, of Fuel, in Fire-En-

" 'gines,' which passed the seals in January, 1769;
" and my Specification was enrolled in Chancery
" in April following."

Mr. John Hart, an ingenious tradesman of Glasgow, who was a native of Borrowstoness, and, together with his brother, was distinguished by a predilection for the practical arts connected with science, has related that Mr. Watt frequently conversed with him on subjects of mechanical interest; and that being asked by him, in 1817, whether he recollected how the first idea of his great discovery came into his mind, he replied, "O yes,
" perfectly. One Sunday afternoon I had gone
" to take a walk in the Green of Glasgow;* and
" when about half way between the Herd's House
" and Arn's Well, my thoughts having been
" naturally turned to the experiments I had been
" engaged in for saving heat in the cylinder, *at*
" *that part of the road* the idea occurred to me that
" as steam was an elastic vapour, it would expand,
" and rush into a previously exhausted space; and
" that if I were to produce a vacuum in a separate
" vessel, and open a communication between the
" steam in the cylinder and the exhausted vessel,
" such would be the consequence." Mr. Hart has further mentioned that the workshop of which Mr. Watt at that time made use, was "a small
" one in the back building of the first entry to the
" north of the meat-market in King-street."†

* "The large open meadow which lies on the northern bank of the " Clyde, and serves at once as a bleaching-field and pleasure-walk for " the inhabitants."—Sir W. Scott, ROB ROY, chap. xxi. Abbotsford edition, vol. iii. p. 165.

† From a MS. notice communicated by the late Dr. John Smith, of

Without dwelling on the particular scenes of these minute recollections, which, however, may in future interest the local topographer and antiquary, we do not fear being accused of undue repetition if we lay before the reader a more careful history, also given by Mr. Watt, of the origin and early progress of his inventions, in so far as they were specified in relation to his first patent. This interesting document was prepared by him in 1796, as a general answer to the objections which his opponents, in the litigation already referred to, raised to the specification. Expressed in language both precise and clear, it was originally intended for the information of counsel, and, through them, of the Court; and was by its unassuming author, with characteristic simplicity, entitled—

A Plain Story.

"W. found that a well-made brass model of "Newcomen's engine, consumed quantities of "steam and fuel out of all reasonable or direct "proportion with larger engines. He consulted "Desaguliers' 'Natural Philosophy,' and Belidor's 'Architecture Hydraulique,' the only books "from which he could hope for information. He "found that both of them reasoned learnedly, but "by no means satisfactorily; and that Desagu"liers had committed a very gross arithmetical "error in calculating the bulk of steam from the

Glasgow, long the respected Secretary to the Maitland Club; to which literary society he, in 1832, presented the "Burgh Records of the City "of Glasgow, M.D.LXXII—M.D.LXXXI."

" water evaporated in a common steam-engine;
" which being rectified, it appeared next that his
" data, or assumed facts, were false. By a simple
" experiment, W. found what was the real bulk of
" water converted into steam; and from his friend
" Dr. Black he learned what was the heat ab-
" sorbed and rendered latent by the conversion
" of water into steam, which the Doctor then
" publicly taught, and had done for some years.
" Experiments had been made long before by Dr.
" Cullen, Mr. John Robison, and others, in public
" classes, which proved that water, when placed
" in an exhausted receiver, boiled, and was con-
" verted into steam at the heat of 70° or 80° of
" Fahrenheit's thermometer, while it was well
" known that under the pressure of the atmo-
" sphere it required 212° of heat to make it boil,
" and emit steam capable of displacing the air.
" It was evident that under intermediate pressures,
" intermediate degrees of heat would be required
" to make it boil, and that in the steam-engine
" more or less cold water must be thrown in
" according to the degree of exhaustion which
" might be required; or, in other words, according
" to the number of pounds per inch the engine
" was loaded to.

" Newcomen's and Savery's engines existed;
" the latter were in general laid aside, on several
" accounts, but the principal one seems to have
" been that the cold water, the raising of which
" formed the effect of the engine, entered the
" steam-vessel itself, which in general was not a

" cylinder, but was of an oval or egg form; and, " by cooling it, destroyed a great quantity of steam " when it came next to be filled, which Desagu- " liers expressly notices. This engine, however, " had an injection of cold water, to commence the " condensation of steam, and Savery seems to " have been the inventor of that valuable article;* " but he also seems in some cases to have con- " densed the steam by pouring cold water on the " outside of his copper steam-vessel.

" In Newcomen's engine the steam-vessel was " a cylinder, or so meant to be. A piston was " suspended, moveable in that cylinder; this piston " hung by chains to the arch of a strong double- " ended lever like a scale-beam, to the other end " of which the rods which wrought the pumps " were suspended in the like manner. The " steam was admitted from a covered boiler, " through a pipe, into the cylinder below the " piston; the air was blown out by the steam at " a pipe near the bottom of the cylinder, called " the *snift*. The passage from the boiler was shut; " cold water was spouted or injected into the " cylinder from a cistern placed higher; the steam " was thus condensed or rendered less elastic, the " other end or mouth of the cylinder being open; " the pressure of the atmosphere, not being re- " sisted by an equally elastic fluid within, or under " the piston, weighed upon the latter and caused " it to descend, which, by means of the lever, drew

* See note on vol. ii. p. 233, *infra*.

" up the pump-rods and raised the water. The " injection-cock or valve was then shut, the steam- " regulator or valve was opened, steam was re- " admitted, the equilibrium of pressure upon the " upper and under sides of the piston was restored, " and the superior weight of the pump-rods, by " means of the great lever or working beam, drew " the piston to the top of the cylinder, and the " operation recommenced. When the piston was " at the bottom of the cylinder, the air which " entered with the steam and with the injection " water was blown out at the snift, and the hot " water left in the cylinder was expelled through " another pipe, called the *eduction-pipe*, which " proceeded from the bottom of the cylinder, " several feet downwards, and its lower end stood " in a cistern of water, and was furnished with a " valve to prevent regress.

" The steam-valve and the injection-cock were " opened and shut by certain mechanism called " working gear, which was put in motion by means " of pegs in a piece of wood which was hung to " and moved with the working beam, and was " called the plug-tree.

" In order to supply the engine with cold water, " it wrought a pump called a jack-head pump, " which was shut at top by an iron cover, and its " pump-rod wrought through a collar of oakum, " which permitted the rod to slide up and down " while it precluded the exit of the water, which " was raised to a greater height through a side " branch turned upwards.

"Thus the latent heat of steam was discovered "and published by Dr. Black;—the boiling of "water *in vacuo*, at low degrees of heat, was dis- "covered and published by Dr. Cullen, Mr. Robi- "son, and several others.

"The elastic powers of steam were known to "Hero of Alexandria, and to many ancient "writers. The steam-engine was invented by the "Marquis of Worcester, Savery, Papin, and New- "comen.

"The means of confining steam, and the making "valves, cocks, and regulators, were known to all "of them. Pumps for drawing both air and water "out of vessels or reservoirs were well known to "everybody. An air-pump, with a piston-rod "*moving through a collar*, was invented and pub- "lished by Mr. Smeaton; and the same method, "even before him, was commonly used in the jack- "head pumps of common steam-engines and in "other machines:—(this relates to the piston-rod "of the cylinder; for in respect to the air-pump "it is not necessary, though convenient, that it be "shut at top.)

"A cylinder and moveable piston were used in "Newcomen's engine; so were the working beam "and working gear, or machinery for opening and "shutting the valves and cocks.

"The steam was condensed by a spout of cold "water in Savery's and in Newcomen's engines; "and, as it is said in Desaguliers, cold water was "poured on the outside of the steam-vessels for "the same purpose. Everybody knew that cold

" bodies of all kinds condensed steam when they " came in contact with it. There were pipes in all " those engines which admitted the steam from " the boiler, and cocks or valves which shut it " out from that vessel; and in Newcomen's engine " there was a pipe which conveyed away the hot " water, and a valve which prevented its regress.

" The diameters of those pipes, which admitted " the steam and let out the injection water, had " been ascertained sufficiently near. The size and " form of boilers, which answered sufficiently well, " had also been ascertained.

" Of all those things, Watt must say, '*Non ea* " *nostra voco.*' The things that are his remain to " be told.

" He found, by the application of the knowledge " which has been mentioned, that the cause of the " great consumption of fuel was, that the cylinder " being cooled by the injection-water, that vessel " *must* condense a large quantity of steam when- " ever it was attempted to be again filled with " steam; that the vacuum could not approach to " perfection without the steam was cooled below " 100°; and that such cooling would increase the " evil complained of in a fourfold or greater ratio, " because the penetration of the heat or cold into " the cylinder would be as the squares of the differ- " ences of the heats between that vessel and the " steam. How was this to be avoided?

" He tried to make the cylinders of wood or " other materials which conduct heat slowly, but " he could not prevent the steam from coming

" into contact with the comparatively cold water " which remained in the bottom of the cylinder, " and which must be expelled by the steam; be- " sides, his wooden cylinders did not seem likely " to be of long duration. In such-like experiments " he spent much time, and more money than was " suitable to his circumstances, yet he made no " advances towards a beneficial discovery. But " the matter having got firm hold of his mind, " and his circumstances obliging him to make " exertions to regain what he had spent, he turned " the matter over in every shape, and laid it down " as an axiom,—*that to make a perfect steam-engine,* " *it was necessary that the cylinder should be always* " *as hot as the steam which entered it, and that the* " *steam should be cooled down below* 100° *in order to* " *exert its full powers.* The gain by such construc- " tion would be double:—first, no steam would " be condensed on entering the cylinder; and " secondly, the power exerted would be greater as " the steam was more cooled. The *postulata,* how- " ever, seemed to him incompatible, and he con- " tinued to grope in the dark, misled by many an " *ignis fatuus,* till he considered that steam being " an elastic fluid, it must follow the law of its " kind; and that if there were two vessels, A and " B, of equal or other dimensions, the one, A, " filled with steam, and the other, B, exhausted, if " a communication were opened between those " vessels, the steam would rush from the full one " into the empty one, and they would both remain " half exhausted (if the vessels were equal in size),

" or be filled with steam of half the density. If, " then, into the second vessel, B, an injection of " cold water were made, or cold water applied to " its outside in sufficient quantity, the portion of " steam which it contained would be condensed or " reduced to water; and by the same law of " nature that had operated before, more steam " would issue from A into B until the whole was " condensed, and nearly a perfect vacuum esta- " blished in both vessels; yet as the cold water " had not entered or touched A, that vessel would " still retain its heat.

" This idea once started, the rest immediately " occurred. The vessel A being supposed to be " the cylinder, B would be the vessel called now " the condenser; the water, air, &c., accumulated " in B, he immediately saw could be discharged or " drawn out by means of a pump, or the water " might be let run out by a pipe more than " 34 feet long going downwards, and the air " might in that case be expelled at a valve by " filling B with water, provided the descending " eduction-pipe were shut meanwhile. On the " whole, however, he preferred the pump. An- " other difficulty appeared, which was the making " the piston tight. That could not be done with " water, as in Newcomen's engines; for that " might get in and evaporate, and produce steam. " He therefore thought of wax, oil, and similar " substances, as substitutes, knowing that they " would not evaporate in the heat of boiling " water; and, for greater security, he proposed to

" employ the steam itself as the acting power on " the piston.

" The diameters of the pipes necessary to convey " the steam into and out of the cylinder, he regu- " lated from those in use. The size of the con- " denser he assumed at random, as he did that of " the air-pump, which it was evident must be " larger than was necessary to contain the water " and probable quantity of air. All this passed in " his mind in the course of a few hours; and in a " few days he had a model at work, with an in- " verted cylinder, which answered his expectations, " and was, as far as he remembers, equal in its " properties of saving steam and fuel to any he has " made since, though in point of mechanism much " inferior. Very simple cocks were employed as " regulators or steam-valves, and his air-pump " and condenser were of tin-plate. His cylinder, " however, was good, and of brass, [about] 2 inches " diameter and a foot long; the cocks were turned " by hand instead of being wrought by the engine.

" If Mr. W. is thought worthy of credit in this " matter, and the facts are consequently allowed, " where was the mighty difficulty of putting the " invention in execution from still fewer data than " he has set forth in his specification? He is not " so presumptuous as to think that there were " not, and are not, numbers of mechanics in this " nation, who, from the same or even fewer hints, " would have completed a better engine than he " did. Mr. Bramah has proved* that he could,

* *i. e.* Given it in evidence.

" and W. is inclined to believe him. But W. " does not pretend that *any body* could have done " it without *thinking* upon it, nor without much " previous knowledge and some experience of " similar things.

" Had W. been content with the mechanism of " steam-engines as they then stood, his machine " might soon have been brought before the public; " but his mind ran upon making engines *cheap* as " well as *good*, and he had a great hankering after " inverted cylinders and other modifications of his " invention, which his want of experience in the " practice of mechanics in great, flattered him " would prove more commodious than his matured " experience has shown them to be. He tried, " therefore, too many fruitless experiments on " such variations. He wanted experience in the " construction of large machines; that he endea- " voured to acquire; but experimental knowledge " is of slow growth, and with all his ingenuity, " *so much boasted to his prejudice*, he was concerned " in making some very indifferent common en- " gines. Other avocations, to him necessary, " obliged him to turn his attention from the sub- " ject till he obtained the patent, so that at that " time he had made no advances in the improve- " ment of the mechanism. He therefore thought " it proper to specify only what was his invention, " and to leave any mechanical improvements he " might make to be secured by other patents, if " worthy of them.

" His idea, then, was to apply his invention to

" the steam-engines as they existed. For this " purpose there was nothing else necessary than " to shut up the snift, to apply a regulator or " valve to the opening of the eduction-pipe within " the cylinder, an air-pump to the outer end of " that pipe, and to inject into the upper end of " the eduction-pipe. If, at the same time, the " cylinder was defended from the cold of the " atmosphere, the engine would thus be complete, " if the weight of the atmosphere were to be em- " ployed as the acting power; for all the regu- " lators could be easily opened and shut by the " then existing contrivances, and the air-pump rod " could be suspended from the working beam.

" If, however, the engine was wanted to receive " all the advantages of the invention, the cylinder " was to be placed in a case containing steam, " with access for that fluid to the upper side of " the piston, so that it might act upon it as the " atmosphere acted in common engines, or in the " case just stated. And in this latter manner " were the engines made which he constructed in " the beginning of the business; that is to say, " the cylinders were fixed in a case containing " steam, with which fluid they were wholly sur- " rounded; and, their mouths being open within " the case, the steam had always access to the " upper side of the piston, and was admitted to " the part below the piston only when the piston " was rising. The opening from the cylinder into " the eduction-pipe was shut by a valve while the " piston was rising, but when it was required to

" descend, that valve was opened. Those valves " were of the sliding kind used in Newcomen's " engines. The injection was made into the educ- " tion-pipe; and the air-pumps, which drew out the " water as well as the air, were fixed to the bottom " of the eduction-pipe, which had a valve to pre- " vent regress as usual. There was sometimes " one pump, and sometimes there were two or " three, as circumstances or the fancy of the " moment directed. The working beams and " working gear were made in the usual manner, " or nearly so; and in cases where there were " boilers fixed for the common engine, which was " superseded, they were used without alteration.

" These engines, then, differed in nothing from " the ancient ones, except in the application of " W.'s principles as set forth in his specification.

" It was found that the external cylinder, or " steam-case, was very expensive. The method " of covering *the cylinder itself* with a lid or cover, " (which had been used in some of the models), " and conveying the steam to the lower end of the " cylinder by a pipe, was adopted, and a less ex- " pensive method of applying the envelope of " steam was used. Other kinds of regulators were " invented, and the whole mechanism of the engine " was gradually improved, and these improve- " ments have been progressive for the last twenty- " one years. Some of them W. has secured by " other patents, but many of the most essential " he has left free, and by means of them New-

" comen's engines have been improved to his " loss.

" It will now, it is hoped, appear to the candid " that W. has not wilfully concealed his invention " by a false specification, but has set forth the " nature of the same, and the means of performing " it. He has told what he had invented; and it " could not have been expected that he should " have described mechanism already known to all " practitioners, or not then invented.

" W.'s invention is merely a contrivance to " prevent cooling the cylinder, and to make the " vacuum more perfect *by condensing the steam in " a vessel distinct from the cylinder itself*; this is " the nature of the invention. The means of " keeping the cylinder warm,—the substitution of " the powers of steam for those of the atmo- " sphere,—of grease, &c., in place of water to keep " the piston tight,—and the drawing out the air, " &c., by means of pumps,—are merely aids in " performing the principal object. This ought to " be kept in view in judging of the specification; " also that W. supposed it to be addressed to " mechanics, and philosophers, and not to the " ignorant."

CHAPTER VI.

MODEL OF NEWCOMEN'S ENGINE REPAIRED BY MR. WATT — HISTORY OF DR. ROEBUCK, HIS RESIDENCE AT KINNEIL, AND THE ESTABLISHMENT OF THE CARRON IRON-WORKS — HIS COMMERCIAL EMBARRASSMENTS — MR. WATT'S PATENT OF 1769.

WITH regard to the model of Newcomen's engine belonging to the College of Glasgow, and which has attained so great a celebrity by the results which it was instrumental in producing, we find two entries in the records of that University; of which the first is as follows:—"University "meeting, 25th June, 1760. Mr. Anderson is "allowed to lay out a sum, not exceeding two "pounds sterling, to recover the steam-engine "from Mr. Sisson,* instrument-maker at London." The model, (as will presently appear), never having worked well, the reason of it being sent to London had probably been a vain endeavour to have its faulty construction amended. Whether Mr. Watt had seen it, during his stay there, in the

* Of this skilful artificer the learned M. Delambre writes:—"Sisson "fit le quart de cercle de Greenwich, un autre pour l'Observatoire "particulier du Roi d'Angleterre, et le quart de cercle que Lemonnier "rendit mobile. Sisson soutint à cet égard l'honneur *et la pré-éminence* "de l'Angleterre."—Delambre, "Histoire de l'Astronomie au dix-"huitième Siècle," p. 237, 1827.

workshop of Sisson, or how far he may have advised it being brought back to Glasgow, as a subject for further consideration and study, we know not. But the next entry concerning it, in the same records, appears to be this :—"University "meeting, 10th June, 1766. An account was "given in by Mr. James Watt for repairing and "altering the steam-engine, with copper pipes and "cisterns, amounting to 5*l.* 11*s.* The said machine "being the property of the College, and having "been in such a situation that it did not answer "the end for which it was made, the Principal is "appointed to grant a precept for payment of the "said account, which is to be stated upon the fund "for buying instruments to the College."*

This, it will be remembered, was after the idea of the separate condenser had "occurred," which was "early in 1765;" and by the repairs and alterations of the "copper pipes and cisterns" of the machine, its fault of *not answering the end for which it was made*,—(one grievous enough, no doubt, but appertaining to many other machines, both animate and inanimate, in common with it),—had in all probability been effectually corrected. That interesting little model, as altered by the hand of Watt, and preserved in all safety and honour within the precincts of its ancient birth-place, has

* For these extracts from the University Records we are indebted to the kindness of a learned friend, the Rev. Dr. William Fleming; whose high academic praise it is, that he ably and eloquently fills the Chair once occupied by a Hutcheson, an Adam Smith, and a Reid. See also "Deeds instituting Bursaries, &c., in the College and University "of Glasgow," p. 215, 1850.

been appropriately placed beside the noble statue of the Engineer, in the Hunterian Museum;—a sacred relic worthy of such a shrine, and there visited by many a worshipping pilgrim.

From the narratives of both Dr. Black and Dr. Robison, it is apparent that, next to the inventor himself, the person at first most deeply interested in the mechanical and commercial success of the invention, the origin of which has now been so fully detailed, was Dr. Roebuck; an ingenious and enterprising man, whose ultimate want of success in life ill rewarded his fondness for practical science, and his energetic exercise of very considerable talents and industry. It seems indeed a singular fatality, that even his early connection with the greatest invention of his age, full of future profit as it promised to be, and narrowly as we now see that it failed to realise that hope to him, was not only of no ultimate service to his own fortunes, but had nearly cut short the progress of the invention itself; which was long submerged, and well-nigh altogether lost, in the financial wreck in which his affairs became involved.

For the best account of the life and pursuits of

* Such had been, of late years, the felicitous arrangement. But on revisiting the College of Glasgow in January last (1854), "one morn "we miss'd" the model from its apposite home. On inquiry, we found that it had been placed among the apparatus attached to the Natural Philosophy Lecture-room, where, it was alleged, it had dwelt nearly a century ago. As the model, however, belongs to "the College," we hope that this seclusion, so disappointing to the public eye, may be only temporary; and that what might now be fairly said to be "meant "for mankind," may not permanently be imprisoned where it can be open to the inspection of comparatively only a few.

the gentleman who was thus destined to become the temporary though unsuccessful associate of Mr. Watt in his important scheme, the public are indebted to the pen of the late Professor Jardine, of Glasgow College, a person whose memory is deservedly held in veneration by all who in their academical career enjoyed the advantage of his sagacious, instructive, and friendly counsels. From a biographical notice which he communicated to the Royal Society of Edinburgh, and which is published in their Transactions,* we find that Dr. Roebuck, who was born at Sheffield in 1718, and received some of his early education under the care of Doddridge and in companionship with Akenside, studied medicine at the University of Edinburgh, and formed there an intimate acquaintance with Hume, Robertson, and others of their eminent contemporaries. Graduating at Leyden, on his return to England he settled as a practising physician at Birmingham, where he rapidly rose into extensive and lucrative employment, and was at the same time enabled to gratify his inquiring habit of mind by numerous scientific researches, in which he engaged with ardour. The study of chemistry, one of his favourite pursuits, he now prosecuted practically, with great ingenuity and perseverance; inventing improved and economical processes for refining and working gold and silver, as well as for manufacturing many other substances commonly used in the arts; and, in conjunction

* Trans. R. S. E., iv. p. 65, 1796.

with Mr. Samuel Garbett, establishing a large laboratory, where his various processes were profitably carried out on a very extensive scale. Sulphuric acid, which had previously been made, at great expense, in glass retorts, they succeeded, after many experiments, in preparing, by means of leaden vessels, at less than a fourth of its former cost; and on their establishing a manufactory of it at Preston Pans, in East Lothian, the consumption of the article increased enormously, and the profits of their undertaking became proportionally large.

Emboldened by this success, Dr. Roebuck proceeded to carry out a work of far greater extent and importance, which both in a private and in a national point of view has more than equalled the sanguine expectations then formed of its probable utility. Among the numerous subjects to which he had turned his attention, was the smelting of iron-ore; a process which, as then commonly conducted, was capable, he had satisfied himself, of very great improvement. Having, with his partner Mr. Garbett, now realised some fortune by the profits on his other processes, and being easily enabled, by the confidence reposed in his skill and judgment, to obtain the loan of the further capital that was necessary, he resolved to establish in Scotland a manufactory of iron on a great scale. To him was left not only the direction of all that concerned the buildings, machinery, and processes of the manufacture, but, in the first place, the selection of a proper site for the intended works; and on the banks of the river Carron, in Stirling-

shire, he found united every natural facility for his purpose. In that situation, with great water-power, were combined the advantages of ready transport by sea, and supplies, in the immediate neighbourhood, of excellent iron-ore, limestone, and coal,—minerals which, after the lapse of nearly a century, have in that district shown no signs of exhaustion.

The Carron iron-works, in their original state, were completed by the end of 1759, and the first furnace was blown on the 1st of January, 1760. Dr. Roebuck then lived at the house of Kinneil, near Borrowstoness, a "very ancient and very "stately" mansion,* about three miles from Linlithgow, the rural beauties of which were, half-a-century later, thus described by the poet Campbell, while there on a visit to his venerable friend Dugald Stewart:—"Stewart's residence is an old "chateau of the Dukes of Hamilton, agreeably "situated near the sea, opposite the classic Ben-"Ledi, and surrounded by fine groves that resound "with the songs of birds, the cawing of rooks, and "the sweeter cooing of wood-pigeons. The whole "scene, with the society and conversation of my "friends, sinks deep into my mind." †

In planning the Carron machinery, Dr. Roebuck availed himself of the great talents of Mr. Smeaton, who has been justly termed the father of civil-engineering in Great Britain, and who, having in

* Sir David Wilkie; see his Life by Allan Cunningham, vol. i., p. 461.

† Beattie's Life of Thomas Campbell, vol. ii. p. 286.

1750 begun business in London as a philosophical-instrument-maker, was already fast rising to eminence in both of those professions. He had not, however, been previously brought into notice in Scotland; and the introduction of his skill into that country, in which he afterwards directed many important engineering operations, is one of the numerous proofs that Dr. Roebuck gave of possessing an observant and penetrating judgment. Among Mr. Smeaton's Reports, which were published by the Society of Civil Engineers,* and form an interesting memorial of his labours, are included several that were addressed to the Carron Company, concerning the supply and regulation of the water-power, the construction of blowing-machines on improved principles, of mills for boring the great guns known in the British Navy as *carronades*,† and other kindred matters.

* In three volumes, quarto, 1812; which were followed, in 1814, by a fourth volume of his Miscellaneous Papers, comprising all of his communications to the Royal Society, printed in the Philosophical Transactions.

† "In the early part of 1779," says Mr. James, in his well-known and admirable Naval History, "a piece of carriage-ordnance, the invention, by all accounts, of the late scientific General Robert Melville, was cast, for the first time, at the iron-works of the Carron Company, situated on the banks of the river Carron, in Scotland. Although shorter than the navy 4-pounder, and lighter, by a trifle, than the navy 12-pounder, this gun equalled in its cylinder the 8-inch howitzer. Its destructive effects, when tried against timber, induced its ingenious inventor to give it the name of *smasher*." The new gun soon got the name of *carronade*, and those of the larger calibres were found to be so formidable from the force and weight of their shot (from 32 to 68-pounders), that within a very few years of the date of their invention they were introduced into almost every ship in the British navy; while a carronade of smaller calibre (24 down to

The works established under such advantageous circumstances, and directed by such able advice, did not fail to prosper; and they proved a lucrative investment of the means of their principal projector, as well as of his associated friends. Well had it been for all of them had his attention continued to be engrossed by the profitable manufacture which he had thus so energetically created; but, as the various processes were gradually reduced to little more than mere routine, his ardent mind sought fresh scope for exertion, and he embarked in an adventure, which, although at first it had a semblance of further utility and profit, ended in involving his friends in grievous embarrassment, and himself in irretrievable pecuniary ruin. One of the great principles of the improved method of manufacturing iron, as practised at Carron, was the use of pitcoal instead of charcoal; which, although it had certainly been contemplated and even occasionally attempted in practice in England almost a century and a half earlier,* it remained

12-pounders) was in 1795 ordered to be supplied to the launch of every ship of the size of an 18-gun brig or above it, to aid in the service of cutting out vessels from the enemy's harbours.—See "The Naval "History of Great Britain," by William James, vol. i. pp. 47 and 436, ed. 1826.

* See the account of the "Letters Patent of Priviledge" granted successively to Simon Sturtevant in 1612, John Rovenson in 1613, — Gombleton, Doctor Jordan of Bath, and sundry others, in "Dud "Dudley's Mettallum Martis or Iron made with Pit-coale, Sea-coale, "&c., and with the same Fuell to Melt and Fine Imperfect Mettals, "and Refine Perfect Mettals. London. Printed by T. M. for the "Authour, 1665;" a curious little book, of which, the original edition having become extremely rare, an exact and careful reprint was published in 1852.

for Dr. Roebuck successfully to reduce to a general and useful system. An abundant and cheap supply of coal being thus an essential requisite for the continued prosperity of the iron-works, Dr. Roebuck was desirous of securing it by becoming the lessee of the extensive coal-mines belonging to the Duke of Hamilton, at Borrowstoness, where the coal workings were combined with salt-pits. The natural obstacles, however, which presented themselves, (arising chiefly from the great and unexpected depth of the workings), were so formidable as at first greatly to hinder, and ultimately to render hopeless, the success of all his endeavours.

It was after he had engaged in that perilous adventure, but before its fatal issue was ascertained, that Dr. Roebuck was brought into connection with Mr. Watt; their mutual introduction having been, doubtless, owing to Dr. Black, with whom Professor Jardine relates Roebuck to have lived till his death in close habits of intimacy, "often "acknowledging, with much frankness, the ad- "vantages which he derived in his various pursuits, "from a free and unreserved communication with "that eminent chemist." * From the inventive genius of his new acquaintance, Dr. Roebuck was able to discern that great profit might accrue to the extensive establishments under his own care; his judgment, therefore, no less than his inclination, led him warmly to enter into schemes for rendering effectual in practice the principles which

* Biographical Notice, Trans. R.S.E., vol. iv.

Watt communicated to him; and, an unreserved confidence having been established between them, in the correspondence which ensued are to be found the earliest contemporary records of the progress of the great discovery, which, as we have just seen, had "flashed upon the mind" of Mr. Watt in the summer of 1765.

At this stage of advancement it was,—when the great invention had been visibly and tangibly exemplified in a working model, and while its projector awaited, with eager hope, the performance, on a larger scale, of an engine of which most of the parts were already constructed,—that the cloud of pecuniary difficulty which overhung the house of Kinneil increased so as grievously to darken all further prospects; discouraging, although not as yet entirely closing, that series of experimental trials which had hitherto been assiduously prosecuted. In September, 1766, Mr. Watt wrote to a friend: "I think I have laid up "a stock of experience *that will soon pay me for the* "*trouble it has cost me*;" yet it was between eight and nine years before that invaluable experience was made available so as either to benefit the public or to repay the inventor; and a much longer period elapsed before it was possible for that repayment to be reckoned in the form of profit. To Mr. Watt, the embarrassments which at so critical a period, and without any fault or even imprudence on his own part, intervened so as to prevent the fulfilment of his designs, were necessarily the source of great disappointment and vexation. But to

Dr. Roebuck they were still more disastrous, and never ceased to be matter of the most poignant regret; for could he have fully anticipated the future development of the invention which now lay before him, he would have seen in it far more than the restoration of all his most prosperous fortunes of past times. And if it be painful in any instance to trace the downward course of an unsuccessful projector, whose want of success has been attendant on abilities and exertions which, under other circumstances, might have ensured a happier fate, most of all must we commiserate the hardship of his destiny when we see, as in this case, that he was tantalised by having the means of recovery within his very grasp, and yet having let them fall from his hand, rendered powerless by the paralysis of poverty.

In the meantime, for some years longer, Roebuck was contending with his adverse fortune, and Watt incubating on such ideas, and, at intervals, practising such experiments as occurred to him. Both seem,—though, as was natural, in different degrees,—to have continued to entertain tolerably sanguine hopes of the ultimate success of the new "fire-engine;" but neither of them could make any very decided step in advance, from the want, principally, of those easy circumstances, which, whether of time or of money, were now too commonly denied to both of them.

On the 5th of January, 1769, however, the memorable patent for "A NEW METHOD OF LES-
"SENING THE CONSUMPTION OF STEAM AND FUEL

"IN FIRE-ENGINES" was obtained; and the relative specification in due course, that is, within four months afterwards, enrolled. It will be seen from a document printed with the correspondence,* that Dr. Roebuck had agreed, in consideration of receiving an assignation of two-thirds of the property of the invention, to defray the debt (of nearly 1000*l.*) incurred by Mr. Watt in making the previous experiments, and also the expense of the patent, and of any further experiments; while Mr. Watt was "to attend and conduct the experi-"ments." In reality it turned out that Mr. Watt had to meet all the expenses, with the exception of the debt of 1000*l.*, which Roebuck took, as agreed, upon himself; and although the funds thus required were not of any very large amount, they still were such as Mr. Watt might have had extreme difficulty in providing out of his small profits in the regular way of his business. We have ascertained that, at least to nearly the whole extent required for obtaining the patent, they were advanced by Dr. Black; who in this, as well as in many other ways, had both the ability and the inclination to promote the success of the labours of his young friend.

We need scarcely add that the sum thus provided was gratefully repaid, with interest, by Mr. Watt, when days of greater affluence had dawned upon him. But we feel pleasure in making known this instance, which we believe is not a solitary

* See below, vol. ii. p. 47, "Discharge by Mr. Watt to Dr. "Roebuck."

one, in which Dr. Black showed himself ready to aid a deserving neighbour less opulent than himself; as it has been alleged,—probably not altogether without reason,—that the learned Doctor was somewhat penuriously attached to the saving of money. The considerable fortune which he bequeathed to his relations,* certainly bore witness to his prudence as a financier no less than to his success as a physician; but on this subject we cannot do better than quote from one of his letters to Mr. Watt, written in the last year of his life,† in which he says,—"You should study "now to enjoy relaxation from business, and the "amusements which are the most suited to your "taste; but above all, relaxation and ease, and "gentle exercise, and change of air. You need "not be anxious now about your fortune. It is "already abundant, and it will increase constantly, "even while you are sleeping. It is, however, "one of the follies of old age to be too intent "on the accumulation of riches; and I feel in "myself a degree of that inclination. Those of "us especially who have made a little fortune by "our own industry, set a high value on riches on "account of the labour which they have cost us; "and when time has put an end to other enjoy-"ments, one of our greatest pleasures is to in-"crease the hoard. We do not consider that it is "already sufficient for every reasonable purpose. "We have acquired a taste and a habit which we

* See vol. ii., p. 266, *infra*.

† Dr. Black to Mr. Watt, Edinburgh, 1 Feb. 1799.

" indulge. If you can be amused with the works " of Horace, you will find in them many pleasant " allusions to this folly, and ingenious expositions " of the absurdity of it." We can hardly imagine either a more pleasant allusion to the foible in question, or a more sound exposition of the absurdity of it, than those thus delivered by the amiable and philosophic Doctor; whose discourse sounds partly as a warning against the sin, and partly as a rather complacent confession of its commission!

CHAPTER VII.

MR. WATT'S CONSTRUCTION OF ORGANS AND OTHER MUSICAL INSTRUMENTS — MACHINE FOR DRAWING IN PERSPECTIVE — CIVIL ENGINEERING — CHART OF THE CLYDE — SURVEYS FOR THE FORTH AND CLYDE, MONKLAND, PERTH AND FORFAR, BORROWSTONESS, CRINAN, CAMPBELLTOWN, AND CALEDONIAN CANALS — TELFORD'S SUBSEQUENT SURVEY FOR THE CALEDONIAN CANAL.

IN 1763, probably in contemplation of his marriage to his cousin Miss Miller, which took place in July of the following year, Watt had quitted his college rooms for a small abode in the city; both then, and during the whole remainder of his residence in Glasgow, practising housekeeping on a very humble scale. In the retired course of life which, from choice as well as necessity, he appears to have followed, manual labour and mental study were blended in pretty equal proportions; but idleness or mere amusement had certainly no share. He ardently seized every opportunity of extending his acquaintance with the various branches of physical philosophy, and of investigating the principles of its phenomena, as if prophetically conscious that to his untaught but earnest apprehension might be revealed those secrets which hitherto had been hidden even from the wise and learned; endeavouring,—to use an

expression of his own,—"to find out the weak "side of Nature, and to vanquish her." Beyond the necessity for some daily labour in order to earn his daily bread, and his hope,—often, as will be seen, very uncertain,—of future independence, he had little else than the pleasure he found in philosophical pursuits to stimulate or reward his zeal: the toils of his business were severe, and the profitable returns but small; while of those whose society was open to him, there were few indeed who possessed either an equality of learning or a community of tastes with himself. But in his endeavours to subjugate, by the resources of practical art, those natural difficulties which presented themselves to his hand or eye, nothing seemed to deter his zeal or baffle his penetration; a very curious proof of which was afforded by his frequent construction, about the period at which we have now arrived, of musical instruments of perfect compass and tone, although he had himself, by nature, an absolute deficiency of all musical ear.

Professor Robison, in another part of the same document from which we have already made large quotations, gives a remarkable instance of this:—
"A mason-lodge in Glasgow wanted an organ.
"The office-bearers were acquaintances of Mr.
"Watt. We imagined that Mr. Watt could do
"anything; and, though we all knew that he did
"not know one musical note from another, he
"was asked if he could build this organ. He had
"repaired one, and it had amused him. He said,
"'Yes;' but he began by building a very small

" one for his intimate friend Dr. Black, which is " now in my possession. In doing this, a thou- " sand things occurred to him which no organ- " builder ever dreamed of,—nice indicators of the " strength of the blast, regulators of it, &c. &c. " He began to the great one. He then began to " study the philosophical theory of music. For- " tunately for me, no book was at hand but the " most refined of all, and the only one that can " be said to contain any theory at all,—Smith's " Harmonics. Before Mr. Watt had half finished " this organ, he and I were completely masters of " that most refined and beautiful theory of the " beats of imperfect consonances. He found that " by these beats it would be possible for him, " totally ignorant of music, to tune this organ " according to any system of temperament; and " he did so, to the delight and astonishment of " our best performers. In prosecution of this, he " invented a real monochord of continued tone; " and, in playing with this, he made an observa- " tion which, had it then been known, would " have terminated a dispute between the first " mathematicians in Europe—Euler and D'Alem- " bert; which completely establishes the theory " of Daniel Bernouilli, who differed from both " of those gentlemen, about the mechanism of " the vibration of musical chords; and as com- " pletely explains the harmonic notes which ac- " company all full musical notes, overturning the " theories of Rameau and Tartini."

The date of the construction of those organs is

pretty exactly fixed by two letters from his friend Mr. Alexander Cumming, a very ingenious adept in similar pursuits, then resident in London, whose name is well known by his meritorious publications on subjects of mechanical interest.* Writing to Mr. Watt on the 27th December, 1761, Mr. Cumming approves of his scheme for an organ, supplies him with a note of the prices of organ-pipes, and inquires "How gets on fiddle-making?" And on the 8th September, 1762, he expresses himself as "glad of his success in "organ-building," and describes the magnificent instrument of the same kind which he had himself constructed for Lord Bute, at a cost of 2000*l.* Mr. Cumming adds this further notice of his own proceedings in the way of ingenious musical mechanism:—"I have proposed an improvement "on the musical-glasses, (that are played by "moving the wet fingers along the brim), by "making them play with keys; but, as I have as "great a demand in the way of my business as I "can well answer, have put off the thoughts of "that and some other experiments till I have "more leisure." †

* See Translation of Arago's Eloge of Watt, p. 81, *note*. Mr. Cumming was a Fellow of the Royal Society.

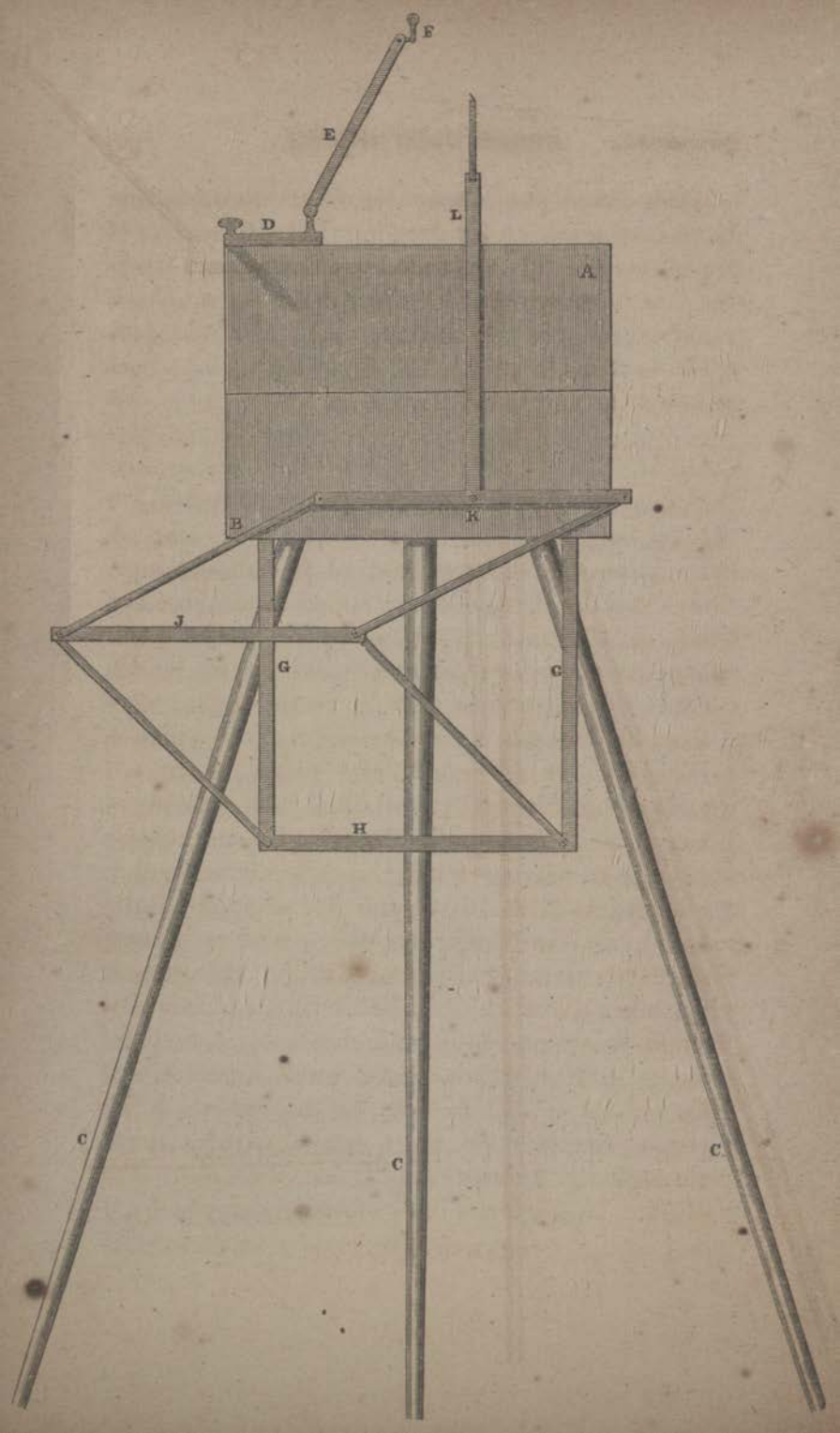
† The organs spoken of in the text were not the only produce of Mr. Watt's musical manufacture; and guitars, flutes, and violins are still in existence, preserved with care by their respective possessors, as curious instances of so extraordinary a parentage; which, indeed, when we consider the co-existence of a physical deficiency in a point apparently essential, must be viewed as little short of a miracle in the works of untutored handicraft.

Some three years later Mr. Watt contrived an ingenious machine for drawing in perspective, of which he has left the following description, together with drawings which are here engraved on wood. (See the two next pages.) His first perspective machine, like his first organ, was constructed for his friend Dr. Black.

Perspective Machine.

"The perspective machine was invented about "1765, on the following occasion. My friend, "Dr. James Lind, brought from India a machine, "invented by some English gentleman there,—I "believe, a Mr. Hurst,—which consisted of a board, "fixed on three legs perpendicularly, upon which, "close to the bottom and near the ends, were "fixed two small friction-wheels, upon which a "horizontal ruler rested, and could be moved "endways horizontally, and this ruler was about "twice the length of the board. On the middle "of this ruler was fixed a perpendicular ruler, "reaching a little above the upper edge of the "board, and in this ruler there was a groove "similar to that of the slip of a sliding rule, which "was also, like that, furnished with a slider which "could freely move up and down in it, and the "upper end of which, being pointed, served for "an index. In the bottom of the groove in the "perpendicular ruler there was a slit cut quite "through the ruler, nearly from one end to the "other. In the lower end of the slider was fixed

* See vol. ii. p. 345, *infra*.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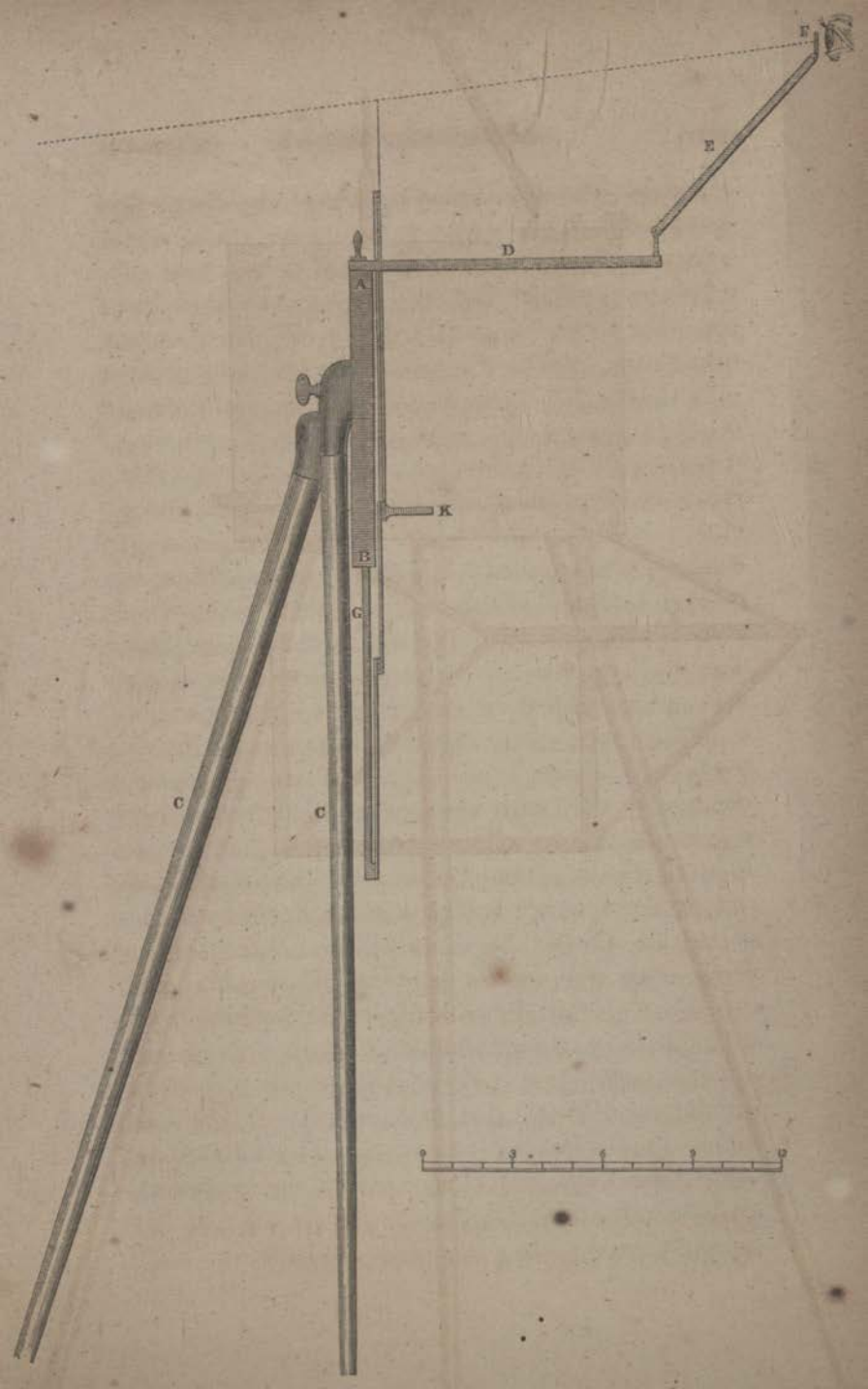
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" a pencil, the point of which reached quite through " the ruler to the paper to be drawn upon, which " was stretched upon the board. An arm pro- " jecting forward was fixed to one of the upper " corners of the board, (I do not remember how), " and upon its end nearest the draughtsman it " carried a sight or eye-piece, consisting of a small " piece of metal with a small hole in it, and this eye- " piece was elevated about half the width of the " board above its upper edge. The rulers, sliders, " &c., were, I think, made of brass, consequently " heavy; but moved easily on the pulleys, or " friction-wheels.

" In using the machine, the board being placed " at right angles to a line supposed to be drawn " from the middle of the object which was to be " delineated, and the sight adjusted so as to give " a proper scale, the socket of the pencil was " taken in the hand, the eye applied to the sight, " and the index or acute top of the slider was " made to travel over the lines of the object to be " delineated, which it was enabled to do by a com- " position of the horizontal motion of the lower " ruler on the wheels, and of the perpendicular " motion of the slider in the upright ruler: the " pencil then described the lines upon the paper. " This instrument very readily described perpen- " dicular or horizontal lines, as these accorded " best with its natural motions. But in diagonal " or curved lines it was difficult to make the " index follow them exactly, and the whole mo- " tions were heavy and embarrassing to the hand.

" Moreover, the instrument was heavy and too " bulky.

" I wished to make a machine more portable, " and easier in its use; and, at the suggestion of " my friend, Mr. John Robison, I turned my " thoughts to the double parallel ruler, an instru- " ment then very little known, and not at all " used that I know of. After some meditation, I " contrived the means of applying it to this pur- " pose, and of making the machine extremely " light and portable.

" The machine consisted of a box about an inch " and a half deep on the outside, thirteen inches " long, and five inches wide, and hinged so that " when opened it formed a flat board (AB) of " thirteen inches long and ten inches wide, on " which the paper was stretched. It was kept " open by means of three legs (CCC), which were " fastened to the back part of it, and served to " support it at a proper height. From the right " hand upper corner of this box or board a jointed " arm (DE) projected forward to carry the eye- " piece or sight (F), which could, by means of the " joints, be adjusted higher or lower, nearer to, or " further from the board, as might be required. " To the lower edge of the board were attached " two thin slips of wood (GG), ten inches long " and ten inches apart, and to the lower ends of " these slips was attached the lower side of a " double parallel ruler (HJK), every member of " which was ten inches long between centres, so " that, when fully open, it formed two squares

" joined by one side of each, and in other states " formed lozenges, or rhombuses of different de- " grees of obliquity. This double parallelogram " was formed partly of thin slips of wood, and " partly of brass much hammer-hardened, and all " very light. To the middle (K) of the upper " side of the higher parallelogram was fixed, at " right angles upwards, another slip of wood (L), " about eleven inches long, and ending in a brass " point which served for an index, which, by the " construction, could be moved equally easily in " every direction, and with very little friction; and, " at the same time, all the positions of the rulers " were always parallel to each other. A pencil, " pressed upon by a spring, was fixed in the junc- " tion of the perpendicular slip or index at K.

" A paper being stretched upon the board, and " the sight being moved to a proper distance from " the board, (generally about eighteen inches,) the " hand being applied to the pencil socket, (for the " pencil was not pressed upon by the hand,) the " upper point of the index was led along the lines " of the objects intended to be delineated; and " when perpendicular lines occurred, the index " pointing to the upper end of them, the finger of " the left hand being applied to the board touch- " ing the perpendicular slip, and the pencil drawn " downwards, the line would be straight. In the " same way, the horizontal slip served as a guide " for horizontal lines; all others were drawn by " the eye guiding the index, and, if the paper was " smooth, could be drawn very correctly.

"The whole of the double parallelogram and "its attached slips, (which latter were contrived "to be easily separated from the board,) were "made capable of being readily folded-up, so as "to occupy only a small space in the box formed "by the board, when folded up. The sight-piece "also folded up, and readily found its place in "the box, which also contained screws for fixing "on the legs of the instrument; and the box, "when shut, could be put into a great-coat pocket. "The three legs were made of tinned iron, taper- "ing, and one a little smaller than another, so "that they went into one another, and formed a "walking-stick about four and a half feet long.

"I made many of these instruments about the "time mentioned;—perhaps from fifty to eighty. "They went to various parts of the world: among "other places several went to London, where "George Adams, senr., copied and made them for "sale, putting his own name on them; and, *as I* "*have been told*, in a book which he published, "describing various instruments, he took the "credit of the invention to himself, or expressed "himself so as to leave that supposable: but I "have not seen the book as far as I can remember, "but have seen the instruments with his name on "them."

The work here alluded to is doubtless "A "Treatise describing and explaining the Con- "struction and Use of new Celestial and Terrestrial "Globes, &c. By George Adams, mathematical "instrument maker to his Majesty. London;

"1766;" prefixed to which, and bound up with it, is "A Catalogue of Mathematical, Philosophical, "and Optical Instruments made and sold by "George Adams, Mathematical Instrument maker "to the King, at his shop, the sign of Tycho "Brahe's Head, in Fleet-street, London, where "Gentlemen and Ladies may be supplied with "*such Instruments as are either invented or improved* "*by himself*, and constructed according to the most "perfect theory." And among the optical instruments is placed—

"A *new* instrument for taking perspective views .. .. £6 6 0."

This, when taken in connection with Mr. Watt having seen the instruments with Adams's name on them, and identified them with those of his own invention, certainly seems to warrant the information he received on the subject. Although, perhaps, the first instance, it was to be by no means the last in which he was to suffer by the application of the "*vos non vobis*" principle. But it was usual with him not to make any public reclamation of even his best-established rights, until forced to do so by a strong pressure; and then, it was only in the most modest, cautious, and unobtrusive manner.

But, while thus incessantly prosecuting his calling, and varying and enlivening its details by numberless instances of ingenious and novel contrivance, his grand idea of a steam-engine working on his principle of separate condensation, was, in silence and obscurity, and through long years of

delay, awaiting its uncertain fate. The necessities of an increasing family led him, in some measure, to forsake the occupation of a mathematical-instrument-maker, (from which, although the extent of his business had become considerable, the returns were not large), for that of a land-surveyor and civil engineer,—a profession the higher departments of which were then little studied or practised in Scotland. Even in England the labours of Brindley and Smeaton had but recently announced the commencement of a new era in that branch of applied science, while to the north of the Tweed they were only just beginning to be known and appreciated as they deserved. The building of the Eddystone lighthouse, perhaps the greatest and most memorable of Smeaton's works, was completed in 1759; and we find that in 1760 he was employed by the magistrates and town council of Dumfries to report on the best means of preserving and improving the navigation of the river Nith.*

"In justice to Father Smeaton," wrote Mr. Watt,† after the lapse of half a century had raised up the gigantic works and established the fame of a Rennie and a Telford, "we should observe that "he lived before Rennie, and before there was "one-tenth of the artists there are now. *Suum "cuique;*—his example and precepts made us all "engineers."

In 1767 Mr. Watt was employed, in conjunc-

* See his Reports, vol. i. p. 1.

† To Sir Joseph Banks, 18 Aug., 1812.

tion with Mr. Robert Mackell, to make a survey for a small canal intended to unite the rivers Forth and Clyde, by a line known as the Loch Lomond passage; which, leaving the Forth some miles above Stirling, was proposed to pass by Bollat into the water of Endrick, and thence, by Loch Lomond and the water of Leven, to Dumbarton on the Clyde. But, as it appeared from Mr. Smeaton's estimates and comparison of that line with another which was called the Carron passage, that the former would cost somewhat more, was more circuitous by nearly forty miles, and would have been attended with an additional loss of time in passing between thirty and forty locks, as well as expenses in keeping them in repair, the latter was preferred, and an Act obtained for the construction of that useful navigation. Mr. Watt having attended Parliament on the part of the subscribers to the Lomond scheme, appears from some of his letters to Mrs. Watt not to have been much enamoured of that public life of which he thus obtained a glimpse; when "close confined attending this "confounded Committee of Parliament," he says, "I think I shall not long to have anything to do "with the House of Commons again:—I never "saw so many wrong-headed people on all sides "gathered together. As Mac says, I believe *the* "*Deevil* has possession of them!"

In 1769 he made a survey and estimate for a

To Mrs. Watt, London, 5 April, 1767.

navigable canal from the collieries at Monkland in Lanarkshire to the city of Glasgow; which was carried out under his own directions and superintendence, to the great advantage of the public as well as of the parties to the undertaking.* In 1770 he was employed, by the Commissioners for managing the Annexed (or Forfeited) Estates in Scotland, to make a survey for a navigable canal from Perth to Forfar, through the valley of Strathmore. In the same year he made a survey and regulations for the contractor for building a bridge over the Clyde at Hamilton; as well as a survey and report on the declivities and state of the bed of that river, by desire of the magistrates of Glasgow, who were then engaged in endeavours to improve its navigation and deepen its channel. The names of the other engineers with whose Reports on the same subject that of Watt has thus been associated, viz. Smeaton, Golborne, Rennie, Whidbey, Clark, Hartley, and Walker, bear conspicuous testimony to the advancement which Mr. Watt was now rapidly attaining in such pursuits, as well as to the clear-sighted discernment and public spirit of those who thus employed him. The progressive and extraordinary increase of the opulence and commercial consequence of Glasgow as a port, has most signally manifested the ad-

* For two years and a half, from June, 1770, to December, 1772, he filled the office of engineer of the canal, at a salary of 200*l.* per annum, which he considered a liberal allowance, and which he only resigned on the completion of his work, and his engagement in other business of a similar kind.

vantage of such engineering operations, when conceived with sagacity, directed by a spirit of liberality, and executed with energetic vigour. Of this, no stronger proof can be given, than the fact that whereas in 1770 and eighteen previous years the revenue arising from harbour-dues, &c. on the Clyde at Glasgow did not exceed 147*l.*, in 1853 it amounted, as shown by the accounts of the trustees of the river, to no less a sum than 86,580*l.*

* The rate of increase is exhibited in the following table, supplied by the Treasurer to the Trustees, and on the accuracy of which, therefore, the fullest reliance may be placed :—

"CLYDE NAVIGATION. REVENUE.

	£.		£.
"1752 to 1770	147	"To 1820	6,328
„ 1780	1,515	„ 1830	20,296
„ 1790	2,239	„ 1840	46,536
„ 1800	3,319	„ 1850	64,243
„ 1810	6,676	„ 1854	86,580."

We must add that the sum of 147*l.*, stated as the revenue from 1752 to 1770, is the *whole* sum entered as having been received on that account in all those eighteen years;—"if more than this," says the Treasurer, "was drawn, it cannot have been properly entered or "accounted for." The average revenue at that time, therefore, cannot be held to have been more than a fraction over 8*l. per annum*, or *not sixpence a day*. When we contrast this insignificant sum with the princely income realised from the same source in our own time,—showing an increase of more than ten thousand-fold,—we are forcibly reminded, on the one hand, of the feeble spring or tiny rill of the solitary moorlands, and, on the other, of the magnificent estuary, surrounded by a vast and thriving population, and bearing to and fro, in endless succession, the proud navies of merchandise and war.

It appears also, from authentic returns, that during the last twelve months alone, thirty-two ship-builders on the Clyde constructed and contracted for no fewer than 266 vessels, of the aggregate tonnage of 168,000 tons, (thus averaging fully 630 tons each); for which engines are prepared, or are in course of preparation, of 29,000 horse power.

Mr. Watt's survey of the river Clyde, which is in the form of a short Report, must not be confounded with another, in the form of a map, or chart, which had been made by John Watt, senr. (uncle of the engineer), in 1734, and which was engraved in 1759, and published in 1760, by the united cares of James Watt, senr., and his two sons, John and James, the former of whom perished at sea two years afterwards.* "The "survey," writes Mr. W. in 1794, "as far as the "Point of Toward, was done by my uncle before I "was born; the remainder was added by my "father and my brother, from the best authorities "they could collect, but is not over accurate." We have ascertained that several alterations were made on the map, by his own hand, before it was engraved; particularly on that portion of it comprehending the islands of Mull, Islay, &c., which occupies a separate division of the map, and is entitled "Entry to the River and Firth of Clyde "and adjacent islands, according to the best autho-"rities." †

"This gigantic work," said the American Consul at Glasgow, in his address to the magistrates of that city on a recent public occasion, "throws your competitor Liverpool, and even colossal London and her "famous Thames, into the shade."

Well, then, may the ancient city, though the "Salmon-fishings" have long been severed from her see, retain in her armorial bearings the fish and jewelled ring of Kentigern—emblems of her productive river; and long may her motto, as heretofore, auspiciously prevail—"LET GLASGOW FLOURISH!"

* See the Translation of Arago's Eloge of Watt, p. 9, *note*, 1839.

† As copies of this work are now rarely met with, we may add, for the information of the curious in such matters, that the name of the

In 1771 he gave in a Report on the best means of improving the harbour of Ayr, and made a survey for a canal of junction between the great (Forth and Clyde) canal and the harbour of Borrowstoness. In the same year he also surveyed lines for canals of junction between the Frith of Clyde and the Atlantic, at Crinan and at Tarbert, for the Commissioners for managing the Annexed Estates; his report on those two lines being prepared and delivered in the following year. In 1773 he made a survey of a canal from Macrihanish Bay, on the western coast of Argyleshire, to Campbelltown, for the conveyance of coals; also of a canal from Hurlet to Paisley, and of the channel of the Water of Leven; as well as a survey, by desire of the Lords Commissioners of Police, for the purpose of rendering navigable the rivers Forth, Gudie, and Devon. To these were added a number of plans, mensurations, levellings, and estimates, at the request both of corporate bodies and of private individuals, which need not here be further particularised;—although among the number were some of very considerable local

engraver was Thomas Phinn, Edinburgh; that the size of the copper-plate was 29×21 inches; and that the impression struck off in 1759 consisted of 450 copies. The expense of engraving and printing was 20*l.*

For the possession of an excellent copy, rendered additionally interesting by some MS. additions of dates and names in the handwriting of the great engineer, we are indebted to the kindness of William Davie, Esq., the present much-respected town-clerk of the city of Glasgow; whom, in his capacity of Secretary to the Trustees of the River Clyde Navigation, we have also to thank for the table of revenue given in our previous note.

importance, such as plans for Port-Glasgow Docks and Harbours, 1769-1772; for supplying the town of Greenock with water, 1772-1773; &c. &c.

But the last and most remarkable of his civil-engineering works was that which he was called on, also in 1773, to perform for his employers the Commissioners of Police; viz. a survey and estimate for a navigable canal, to pass through the chain of rivers and lakes in the wild and remote tract of country between Fort-William and Inverness; being the same line in which, at a considerably later period, the celebrated Caledonian Canal was successfully constructed by Mr. Telford. That great engineer, throughout the whole of his lengthened labours in connection with so vast an undertaking, has borne testimony to the particular correctness and value of Mr. Watt's survey; a circumstance which will be our sufficient excuse if for a moment we anticipate the course of our narrative, to explain the gratifying circumstances in which Mr. Watt at length witnessed the completion, on an enlarged and magnificent scale, of that great national work, on behalf of which his early skill and energy had thus been enlisted. He had also in the meantime* been consulted, as to the same line, by Mr. Rennie; whose scheme, however, was not then carried out.

On Telford's return from Scotland towards the end of the year 1801, he wrote to Mr. Watt, informing him that he had been engaged there since

* Mr. Rennie to Mr. Watt, 19 May, 1793.

the month of July, employed in making surveys by order of the Treasury Board, one of the objects prescribed to him being to examine the country from Loch Linnhe to Inverness, as to the practicability of making an inland navigation; and expressing a strong desire to see Mr. Watt's earlier survey of that district, in order by it to correct his own observations. His letter* concludes:—"We cannot spare you yet; you have done much good, and you must do more still. I cannot positively insist upon your personally making good the Spanish compliment, 'Live a thousand years,' but I may safely presume that your name will deservedly live for ever." "I have so long accustomed myself," he adds in a subsequent letter,† "to look with a degree of reverence to your work, that I am particularly anxious to learn what occurred to you in this business while the whole was fresh in your mind. * * The object appears to me so great and so desirable, that I am convinced you will feel a pleasure in bringing it again under investigation; and I am very desirous that the thing should be fully and fairly explained, so that the public may be made aware of its extensive utility. If I can accomplish this, I shall have done my duty; and if the project is not executed now, some future period will see it done, and I shall have the satisfaction of having followed you in promoting its success."

* Mr. Telford to Mr. Watt, 6th December, 1801.

† Mr. Telford to Mr. Watt, 17th December, 1801.

In 1802 also he again writes to Mr. Watt that he had found an abstract of his Report published in a Report which Dr. Anderson made to the Lords of the Treasury:—"I believe it is yours," says Mr. Telford, "because it is just and masterly; and "I have introduced in my Report your general "description, plainly saying that it could not be "so well told in any other words."

Mr. Telford says that, on comparison, he found the whole of Mr. Watt's statements in his survey "particularly correct, except in the fall from "Loch Oich to Loch Ness, where we differ a few "feet; but the states of the water in the Lochs "make some difference, and the only bad weather "I experienced was during this part of the "survey, so that I am not positive that I am "right. I had not time to prove the levels, nor "is it of much moment: the height of the water "in Loch Oich above the tideway is 100 feet, as "near as may be."* To which Mr. Watt replied:—"As we agree upon the level of Loch "Oich the summit, any difference of level elsewhere cannot materially affect the estimates, as "the feet of lockage will remain the same. The "mistake may, however, be mine, as my levels "were not repeated."†

The depth of water recommended by Mr. Telford was 22 feet. That of the canal as executed was in most parts 15 feet; although the bridges and locks were prepared on a scale to admit of

* Mr. Telford to Mr. Watt, 3 May, 1802.
† Mr. Watt to Mr. Telford, May 9, 1802.

that being increased, should it ever be found advisable, to 20 feet. In his Report,* Mr. Watt mentions that he confined his estimates to a canal of 10 feet depth of water, because he knew of none that had been executed upon a greater scale, and because his views in making the survey were principally directed to those dimensions. "It is "sufficient," he adds, "in a first survey, that the "possibility is established, and the expense of one "mode of communication is nearly estimated, "which I flatter myself I have done. If from my "observations the making any communication

* Mr. Telford introduces a long extract from Mr. Watt's Report, with the following observations:—

"In the year 1773, the Trustees for the Forfeited Estates employed "Mr. Watt to make a survey of this track, which he did, and fur- "nished them with a report and estimate of the expense of making a "canal of ten feet water. This report is so able and just, that had I "considered that size of canal as most advisable, I should have adapted "the calculations of the expense to the present day, and mentioned "some alterations which have taken place in the country since his "survey was made, and should have recommended the survey to your "Lordships' attention. But Mr. Watt's views were merely to ascertain "how far a navigation of any sort was practicable, and therefore he "fixed upon ten feet of water as an assumed standard to enable him "to make his estimates.

"I lose therefore the benefit of his particular calculations; and I "am under the necessity of departing, in some instances, from his line "of canal, especially at the entrances into the lochs and tideways, in "order to obtain a greater depth of water; but I have followed him "wherever the circumstances would permit; and I cannot resist the "introducing his general description of the country through which the "navigation is proposed to be made, because, after having examined "the whole with care, I find it to be so correct, that I could only re- "peat the same descriptions and dwell upon the same points."—Third Report on the Survey of the Coasts of Scotland, ordered to be printed 14th June, 1803, Appendix, p. 32.

(Their levels agreed within one foot.—See p. 42 of the Report.)

" should appear an eligible scheme, the matter " may be minutely examined, and the opinions of " other artists obtained, concerning the best mode " of execution."

It is curious, if only by way of contrast with the practice of the present day, to record the rate of payment at which the skill and exertions of a man endowed with Watt's powers of mind were then obtained. The Strathmore survey of 1770 may be taken as a specimen. On that occasion he was actively engaged in travelling and in field operations for forty-three days, usually from eight or nine in the morning till seven or eight at night, during most inclement weather, with piercing cold, and frequent and heavy falls of snow and rain; and his exertions so much exhausted his strength, as to render him, to use his own words, " unable for some time to apply him- " self to any other business that required atten- " tion." His charge for that work was 80*l.*, or about 1*l.* 17*s.* per diem, *inclusive of all his expenses of travelling and living.* For the preparation of the Report and directing the execution of the map which accompanied it, he was paid the further sum of 30*l.*—an almost equally insignificant recompense for the mere amount of time and labour bestowed, independent of all considerations of superior knowledge, accuracy, and sagacity.

That the rate of remuneration of civil engineers did not rise in any very rapid ratio in the latter part of the last century appears from a letter of Mr. Watt in 1791, in which it is incidentally

mentioned that Mr. Rennie, "who is in consider-
"able fame, and, I suppose," says Mr. Watt, "as
"well paid as any of his standing, has two
"guineas a-day when employed as an engineer;"
in addition, however, it is to be presumed, to his travelling expenses and other "costs and outlays," which was not the case with the smaller rate of pay of Mr. Watt in 1770.

We have in our own time seen engineering bills, in which the rate of charges presented a marvellous contrast to those which men such as Rennie and Watt felt it right to make; while it was also found, to the further serious cost of those who had to defray the far larger amount, that the services received by them for their money were of very far less than equivalent worth!

CHAPTER VIII.

MR. WATT'S INVENTION OF MICROMETERS FOR MEASURING DISTANCES — HISTORY OF THE INVENTION OF MICROMETERS — SIR DAVID BREWSTER — DE LA HIRE — MALVASIA — AUZOUT AND PICARD — GASCOIGNE — MORIN — ROCHON — MASKELYNE — DEATH OF MR. WATT'S FIRST WIFE — HIS SECOND MARRIAGE.

In Mr. Watt's survey of the Tarbert and Crinan lines, in 1771, he used the micrometer which he had then invented; and of which, as well as of the circumstances which led to his employment and improvement of it, he has left the following account.

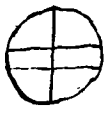
Micrometer for measuring Distances.

"This instrument was contrived about the year "1770 or 1771. I know I used it in the surveys "of the Crinan and Gilp and the Tarbert intended "canals, and also in the survey of the canal from "Inverness to Fort William, now called the Cale-"donian Canal. The former survey was in "1772,* and the latter in 1773, and it was in "1772 I showed it to Mr. Smeaton.

"The instrument I used was a telescope with

* This date, as has been mentioned, is that of the completion of the Report; the actual survey took place in 1771.

" an object-glass of twelve inches and an eye-
" glass of one and a half inch focus; consequently
" magnifying eight times. In the focus of the
" eye-glass there were placed two horizontal hairs,



" (see margin,) and one perpendicular
" hair. The horizontal hairs were about
" one-tenth of an inch distant from each
" other, and as strictly parallel to each
" other and at right angles to the perpendicular
" hair as I could make them. A rod being placed
" upright at twenty chains distant, or any other
" convenient distance, on level ground, an index
" consisting of a round disk of about eight inches
" diameter painted white, with a horizontal line of
" one inch wide painted on its horizontal diameter
" with vermilion, was fixed upon the rod about one
" foot from the ground, and another similar index
" was moved up and down the rod, until upon
" looking through the telescope the two horizontal
" hairs covered the red stripes on the lower and
" upper indexes, the telescope being turned on its
" axis until the perpendicular hair was parallel to
" the rod. The indexes being thus covered by
" the horizontal hairs accurately, the upper index
" was fixed to the rod, and the distance between
" the middle of the red stripes on the two indexes
" was divided upon the rod into twenty parts, re-
" presenting so many chains, which with the in-
" strument I used were upon the rod about four
" and a half inches each, and for distances exceed-
" ing five chains this division into equal parts was
" sufficiently accurate; but for shorter distances it

" is not strictly so. I therefore fixed a pin at " every chain, and holding up the rod at each of " them made the necessary correction, and as the " focus of the object-glass is also affected by the " distance, it is proper to adjust the eye-glass to it " at each station.

" The divisions on the rod being marked with " the number of chains they represent, it was only " necessary to send an assistant with the rod to " any place the distance of which was wanted to " be measured, and by signs to make him move " the upper index up and down until the two " horizontal hairs covered the red stripes on the " upper and lower indexes; the divisions on the " rod then showed the distance, which I found " could be ascertained to within less than one- " hundredth part of the whole distance, and with " a higher magnifying power could be done pro- " portionally more accurate. The rod I commonly " used was twelve feet long, and consequently " could measure thirty chains; but by sliding " another rod upon it so as to lengthen it, I mea- " sured greater distances; and when still greater " were wanted, I stretched a tape horizontally, " and, turning the telescope on its axis, made the " single hair parallel to it, fixing one index at the " end of the tape, and sliding the other along it " until it subtended the distance between the " wires. I then measured the subtended tape " with the rod, and so ascertained the distance; " but this expedient I rarely had recourse to, " the distances I generally had occasion to mea-

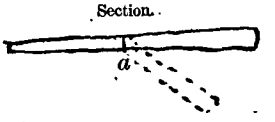
" sure rarely exceeding half a mile, or forty " chains.

" It is plain that this instrument possesses the " advantage of measuring all distances with equal " accuracy, until the imperfection of vision at " great distances interferes, as the scale on which " they are measured expands with the distances; " and in uneven ground it possesses more accuracy " than the chain, and is very valuable in measur- " ing distances from one hill to another, and " across bays of the sea, where the chain cannot be " used. This I experienced in the survey of West " Loch Tarbert, the northern shore of which is " very much indented, and so rocky that it is " scarcely possible to measure a few chains in a " straight line upon it.

" I showed the instrument to all my friends at " the time, and among others to Mr. Smeaton, as " I have mentioned; and used it publicly in my " surveys, and it was consequently known to " many people, though not published in print. A " Mr. Green, in 1778, applied to the Society of " Arts for a premium for the same invention, " which Mr. Smeaton apprised me of, and also " informed the Society of my claims; in conse- " quence of which I was desired to attend their " committee, where I informed them of what I " had done, and at what time. Yet the Society " thought fit to award Mr. Green the premium, " though his invention or use of the method was " posterior to mine,—I suppose because he had " used an instrument of higher magnifying power,

" viz. forty, and consequently had been able to " measure greater distances, and, as was said, with " greater accuracy. I made no further reclama- " tion, as I perceived it was not in that court I " could obtain justice; and as I abhor paper war " I did not apply to any other, though there were " people then living who could have attested my " use of it.

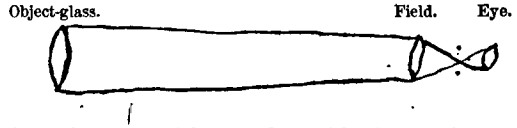
" Another micrometer, with a prism, I in- " vented, I think, about that time. It consisted " of a thin prism almost parallel (say of one " degree or two). This prism " was cut by a diamond into " two parts, which, when they " were fixed in the same



" plane, refracted all the rays which passed through " them equally; but one of them remaining fixed, " and the other moving on a centre at *a* (accord- " ing to the pricked line), would refract that por- " tion of the rays which passed through it more " than those which passed through the fixed part; " and being fixed in the focus of the object-glass " of a telescope, two images were formed of each " object, by which its diameter could be mea- " sured. An index and divided sector of a circle " served to measure the comparative refractions. " This instrument I made with the sector and " radius of wood, and gave it to Professor Ander- " son, of Glasgow College, and I suppose it is still " among his apparatus, which he left to a public " institution. The Abbé Rochon afterwards (1783) " published a description of some micrometers with

" prisms, but I think they were upon somewhat
" different principles in their construction.

" The cross-hair micrometer, as described, leav-
" ing me too much in the power of my assistants,
" where the distances were greater than permitted
" me to read off the number of chains on the rod
" myself, I set about another about 1772 or 1773,
" which consisted of a telescope with an object-
" glass of a long focus, say three or four feet:
" this was placed in a tube with a slit in one side
" of it nearly as long as the focus of the telescope,
" and the object-glass being fitted to a short tube
" which slid from end to end of the slit, could be
" moved backwards and forwards by means of a
" piece of metal fixed to the short tube and coming
" out through the slit: a glass of six to nine
" inches focus was also fixed in the outer tube, in
" the nature of what is called a field-glass, and to
" this was added an eye-glass with a cross-hair
" piece in its focus; thus—



" Now it is evident that if the object-glass be
" moved nearer the field-glass, their common focus
" will be shortened, and the image at the cross-
" hairs diminished, proportionably, until, when the
" glasses come into contact, their common focus
" will be shorter than that of the field-glass alone;
" and two indexes fixed upon a rod being sub-
" tended by the cross-hairs at any given distance,

" the same rod with its indexes being removed
" nearer the observer, upon sliding the object-
" glass nearer the eye they may again be sub-
" tended by the cross-hairs; a scale on the side of
" the tube will show the comparative distance
" they have been removed, and the distance of the
" first being known, that of the second will also
" be so. This scale would not, however, be a
" scale of equal parts, but one which could easily
" be laid down.

" I made a rough model of this instrument at
" the time, but have never completed it, having
" been mostly since in a line of business where
" such instruments were unnecessary. I described
" it, however, to several of my friends at the time,
" and among others to the late Mr. Ramsden; but
" whether it has been thought of by any one else,
" or the problem published, I am ignorant."

Sir David Brewster, at a later period, but without any knowledge of the instruments which had been thus contrived by Mr. Watt, invented an improved micrometer with a moveable object-glass, which is described in his " Treatise on New Philo-
" sophical Instruments in the Arts and Sciences,
" with Experiments on Light and Colours."* But in a review of that work in the " Bulletin de la " Société Philomathique" for 1814,† M. Arago

* Edinburgh, 1813, 8vo.

† " Un instrument entièrement semblable à celui-là avait été em-
" ployé par Roëmer et Lahyre, comme on peut le voir dans le Recueil
" de l'Académie des Sciences pour 1701. M. Brewster n'avait
" sûrement pas connaissance de ces Mémoires, car il propose, dans
" un autre chapitre de son ouvrage (p. 76), de substituer des fils de

having pointed out that the invention of a moveable object-glass for separating, optically, a pair of wires fixed in the focus of a telescope, had been made by M. de la Hire, more than a century before, as is mentioned in the "Mémoires de "l'Académie des Sciences" for 1701,—"I have "since," says Sir David, in writing to Mr. Watt, with the candour by which that eminent philosopher has always been honourably distinguished, "examined M. de la Hire's works, and find that "M. Arago is perfectly correct. This fact there- "fore deprives you and me of all original merit "in the invention of the principle, although you "were as little acquainted with De la Hire's "labours as I was with yours. The idea, however, "of converting it into a general micrometer, of "applying it to the *divided* object-glass (which is "decidedly its best form), and of converting a "Gregorian or Cassigrainian telescope into a "micrometer without any additional lens or mir- "ror, is still mine." *

In the volume to which M. Arago refers, M. de la Hire mentions (Mém. de l'Acad. des Sciences for 1701, p. 128) that, after having composed his

"verre aux fils métalliques ou d'araignée dont on se sert communé- "ment dans le micromètre, et cela sans citer Lahyre, qui avait eu la "même idée il y a plus de cent ans; et qui, de plus, avait décrit avec "détail les moyens ingénieux dont on se sert pour obtenir ces filamens; "ce même astronome paraît aussi s'être occupé le premier des micro- "mètres qu'on peut tracer sur verre avec la pointe d'un diamant.— "(Voyez Mémoires de l'Académie, 1701, p. 119 et suivantes.)" Bulletin des Sciences par la Société Philomathique de Paris, année 1814, Paris, p. 35.

* Sir David Brewster to Mr. Watt, December 12, 1816.

memoir, he found, in the History of the Academy, that M. Roëmer had at an earlier date proposed a micrometer for measuring the diameter of stars, with a moveable object-glass. But the idea of making the micrometric lines either concentric circles engraved on glass with a diamond point, or, if rectilineal, of forming them of threads of glass, appears to have originated with M. de la Hire; who, in another memoir, (Mém. de l'Acad. for 1717, pp. 57-67), explains certain inconveniences which he experienced from such a micrometer when applied to astronomical purposes, which led him to abandon its use, and to suggest yet another sort, which he then goes on to describe particularly.

In the same volume of the Mémoires de l'Académie to which we have last referred, but in another part of it, there is contained another memoir by the same learned and indefatigable author, in which he says that, having observed that there were often great disputes as to who were the first inventors of the micrometer and of the pendulum clock, he thought it desirable to record the result of his own examination of what had been published on that subject, as well as of the private knowledge he had derived from the opportunities with which a very long experience and his intimacy with elder philosophers had supplied him. He then shows that a micrometer with a fixed *virgula* was employed by Huygens, as stated in his book on the System of Saturn, printed in 1659, to measure the diameter of the planets;—that one with cross silver wires was used by the Marquis

Malvasia previous to 1662, in which year that nobleman published his "Ephemerides;"—that in 1666, MM. Auzout and Picard published their account of a much more exact and convenient instrument nearly of the same kind, in which the silver wires were advantageously exchanged for fine silk threads, or hairs;—and he therefore attributes to Huygens the original invention, which had since been progressively brought nearer to perfection.

M. de la Hire philosophically remarks, that, as almost all that is most curious and useful in science and the arts, whether liberal or mechanical, has not at first been invented such as we now possess it, but has attained to perfection only by slow degrees and the labour of different hands, it is very difficult in such cases duly to apportion the merit of the discovery; and he aptly illustrates his position by the history of the invention of telescopes, in which the first step appears to have been quite an accidental one, while subsequent ones were the result of scientific experiment or theory.

To M. de la Hire's honour it is to be observed that he took all possible pains to record the contrivance of MM. Auzout and Picard in all its particulars; for their first account of it, contained in a letter from M. Auzout to Mr. Oldenburg, Secretary to the Royal Society of London, which was printed in a separate form in 1667, but had become extremely rare and difficult to be procured, may fairly be said to owe its preservation princi-

pally to him. He included it in a collection of treatises on various subjects in mathematics, astronomy, and natural philosophy, by different academicians, which was printed in 1693, under his own care. That edition of the Collection was in two volumes folio, but it was soon afterwards reprinted in quarto, in which form it is probably better known, or is at least more accessible to most of our readers, being a portion of that series of the Mémoires de l'Académie which extends from 1666 to 1699. There the paper in question, with an illustrative engraving, will be found at pp. 113-130 of the first part of the seventh volume.

But, after having thus done justice to other countries in recording the share which they took in the invention of the micrometer, it is satisfactory to be able to prove on undoubted authority that ultimately the priority in that invention, so highly beneficial to astronomical science, and "the "application of which first gave to more exact "graduation its peculiar and indeed inestimable "value," * must be awarded to England. Sir John F. W. Herschel,—the illustrious son of an illustrious sire,—has well pointed out that "the "honour of this capital improvement has been "successfully vindicated by Derham (Phil. Trans. "xxx. 603) to our young, talented, and unfortu-"nate countryman Gascoigne, from his correspond-"ence with Crabtree and Horrockes, in his (Der-"ham's) possession. The passages cited by Der-"ham from these letters leave no doubt that, so

* Humboldt's Cosmos, vol. iii. part i. p. 44, ed. 1851.

" early as 1640, Gascoigne had applied telescopes " to his quadrants and sextants, *with threads in the* " *common focus of the glasses*, and had even carried " the invention so far as to illuminate the field of " view by artificial light, which he found ' very " ' helpful when the moon appeareth not, or it is " ' not otherwise light enough.' These inventions " were freely communicated by him to Crabtree, " and through him to his friend Horrockes, the " pride and boast of British astronomy; both of " whom expressed their unbounded admiration of " this and many other of his delicate and ad- " mirable improvements in the art of observation. " Gascoigne, however, perished, at the age of " twenty-three, at the battle of Marston Moor; " and the premature and sudden death of Hor- " rockes, at a yet earlier age, will account for the " temporary oblivion of the invention. It was " revived, or re-invented, in 1667, by Picard and " Auzout (Lalande, Astron. 2310), after which its " use became universal. Morin, even earlier than " Gascoigne, (in 1635,) had proposed to substitute " the telescope for plain sights; but it is the " thread or wire stretched in the focus, with which " the image of a star can be brought to exact co- " incidence, which gives the telescope its advan- " tage in practice; and the idea of this does not " seem to have occurred to Morin. (See Lalande, " *ubi supra.*)" *

* Sir J. F. W. Herschel's Treatise on Astronomy, 1833, p. 86, *note*. See also Humboldt's Cosmos, vol. iii. part i. pp. 44, 59, 64, and 96, ed. 1851.

For a summary of the dispute as to the invention of *prismatic* micrometers, we may refer our readers to M. Mathieu's learned note on Delambre (Histoire de l'Astronomie au dix-huitième Siècle, pp. 645-652, ed. 1827). There the priority is attributed to Rochon, who presented the Academy of Sciences with a description and a specimen of that sort of instrument in January and February, 1777, and in April following reported to the same learned body the measurements of Mars, of Jupiter, and of Saturn with his ring, which he had obtained by its aid.

Maskelyne, who, in December 1777, presented his prismatic micrometer to the Royal Society, produced an attestation by Dollond that he had constructed it for him in the previous year, and taken it to the Observatory at Greenwich in August, 1776.*

To both of those dates Mr. Watt's invention appears to have been antecedent by several years; although of it we may say, as M. Mathieu has done of that of Rochon, "Cet ingénieux instru-" ment ne reçut pas, dans le temps, tout l'accueil " qu'il méritait."

The termination of Mr. Watt's labours as a civil engineer was an abrupt one, accompanied—and indeed in some measure caused—by a melancholy event. Having been suddenly recalled from his survey of the Caledonian Canal in the autumn of

* See the Philosophical Transactions for 1777, vol. lxvii. pp. 799-813, &c. See also Boscovich's "Account of a new Micrometer and "Megameter," *ibidem*, pp. 789-798.

1773 by the intelligence of the dangerous illness of his wife, he had the deep grief of finding on his return home that she had died, after having given birth to a still-born child. Mrs. Watt is described as having been a very amiable person, whose gentle counsels and uniform good temper had often sustained her husband's hopes and animated his exertions under the depressing circumstances of indifferent health, narrow means, and variable and often desponding spirits; from all of which he then suffered in no ordinary degree. By relieving his mind as far as possible of other care, and thus affording it the undisturbed leisure required for study and exertion in his various pursuits, she might even be said to have been of material, though, of course, subsidiary service to him in the progress of his great invention. She earnestly encouraged the hopes which he founded upon it; and even when these seemed for a time to be quite overthrown, her buoyant spirits did not sink, nor did her cheerful faith fail; but she wrote to him, with truly feminine fortitude,—"I "beg you would not make yourself uneasy, though "things should not succeed to your wish. *If it*" [the new steam-engine] "*will not do, something else* "*will. Never despair.*" *

The agony of grief which he suffered on losing so judicious, so beloved, and so faithful a friend, sufficiently appears from those of his letters of that date which have been preserved, although

* August 9, 1768.

some others, it is to be regretted, appear to have been lost or destroyed, probably in consequence of containing no allusion to anything but his private sorrow. Of one, which survives only in the form of an undated fragment, addressed to Dr. Small, but evidently belonging to the period in question, the expressions are gloomy indeed;—more so, happily, than the habitual resignation of its writer to the will of the Supreme Disposer of all events seems ever to have permitted him to repeat. "Let us," he writes, "rejoice in our youth, for "age is dark and unlovely, and in the silent "grave there is no joy, at least that we know of "—vive, et vale."

Of the four children who were the issue of Mr. Watt's marriage with Miss Miller, two died in infancy; one daughter married a Mr. Miller of Glasgow, but died early, leaving issue a son and two daughters (now all dead, the daughters having left issue); and the only son of that family who attained manhood was the late Mr. James Watt, of Aston Hall, who long survived his father as his respected representative, and died, unmarried, in 1848.

Before permanently abandoning his Scottish domicile, and migrating to England *animo remanendi*, Mr. Watt found that the burden of domestic affairs and the care of his children interfered seriously with his other pursuits, which had now become vitally important. He therefore married a second time. The lady of his choice on this occasion was Anne, one of the daughters of Mr. Macgregor, a substantial citizen of Glasgow, who,

under the instructions of his son-in-law, was the first to practise in this country the useful improvement of employing chlorine in bleaching, which Berthollet, its celebrated inventor, communicated to Mr. Watt. She was the mother of Gregory Watt, as well as of a daughter, both of whom she had the misfortune to lose by their premature death; and she died in 1832, in advanced old age, after witnessing the ripeness of the fame of her husband, of whom, M. Arago has justly said, "her various talent, soundness of judgment, and "strength of mind, rendered her a worthy com- "panion."

CHAPTER IX.

MR. WATT'S FIRST VISITS TO BIRMINGHAM AND SOHO — HIS INTRODUCTION TO MR. BOULTON — FORMATION OF THE STEAM-ENGINE PARTNERSHIP OF BOULTON AND WATT — DR. WILLIAM SMALL — THE LUNAR SOCIETY — DR. DARWIN — EARLY SUGGESTIONS OF THE COMPOSITION OF WATER — DR. PRIESTLEY.

We must now turn to another series of events which about this time, in conjunction with those which have just been detailed, led to Mr. Watt exchanging his employment as a civil-engineer for other pursuits still more congenial to his inclination and habits, and destined to raise him to better fortune and higher fame. He had in 1761 passed through Birmingham on his way from Bristol, where he had taken leave of his brother, who was embarking on one of his voyages; but he does not mention having then seen any of the manufactories of the place. In 1767, however, on his return from London, after attending the Committee of the House of Commons on the Forth and Clyde Canal Bill, he visited Soho, being introduced by Dr. William Small, who, along with Mr. Fothergill, a partner of Mr. Boulton's, showed him the works. Mr. Boulton being absent from home, the future friends and associates did not at that time meet. But in 1768 Mr. Watt was again at Soho,

on his return from London, where he had been taking the necessary steps for obtaining a patent for his improved steam-engine; and he was then introduced to the personal acquaintance of Mr. Boulton, "with whom," he says, "I had much "conversation on the subject of the Soho manu- "factures. He explained to me many things of "which I had been before ignorant. On my part, "I explained to him my invention of the steam- "engine, and several other schemes of which my "head was then full, in the success of which he "expressed a friendly interest. My stay at Bir- "mingham at that time was short, but I after- "wards kept up a correspondence with Mr. B. "through our mutual friend Dr. Small.

"In 1773 or 1774; finding that in my then "situation and circumstances I could not bring "my invention into general use, I prevailed upon "Dr. Roebuck, who was then my associate and "patron, to offer his share in the invention to Mr. "Boulton on certain terms; which, after some "hesitation, he accepted, provided he was satisfied "with the invention, on trial at Soho. I accord- "ingly sent to him an engine with an eighteen- "inch cylinder, which I had erected some years "before at Kinneil in Scotland, and followed it "myself in the summer of that year. After suffi- "cient trial, Mr. B. agreed to assist and support "me in obtaining an Act of Parliament for the "prolongation of the patent, which, by his exer- "tions, the assistance of Dr. Roebuck, and [that] "of all the friends we could muster, was obtained,

" after a long attendance on Parliament; after " which, Dr. R. was induced to transfer all his " right to the profits to Mr. B. in consideration of " a certain sum, and Mr. B. entered into partner- " ship with me; his partner, Mr. Fothergill, having " some time before declined taking any share. " Through the whole of this business, Mr. Boul- " ton's active and sanguine disposition served to " counterbalance the despondency and diffidence " which were natural to me; and every assistance " which Soho or Birmingham could afford was " procured. Mr. Boulton's friendly and amiable " character, together with his fame as an ingenious " and active manufacturer, procured us many and " very active friends in both Houses of Parlia- " ment."*

The following anecdote of Mr. Boulton is related by Robison in the MS. document already quoted :—

" I see many of Mr. Watt's contrivances, which " I know to be founded on his perfect acquaint- " ance with the subject, copied by ignorant trades- " men, merely because they are Boulton and " Watt's; and then introduced to their hurt. Such " is the deference with which those persons in " their conscience look up to my friend's superior " skill. And yet (such is the power of avarice), " those creatures will say that Boulton and Watt " steal *their* wonderful inventions! I cannot resist " the present impulse to give a proof how unlikely " these gentlemen are to dirty their fingers with

* MS. Notice of Mr. Boulton by Mr. Watt, in the possession of the Editor.

" such petty larceny. In the summer of 1768 I " took a ride through some parts of England. Mr. " Watt gave me a letter of introduction to Mr. " Boulton, with whom he by that time was a little " acquainted. Mr. Boulton received me with the " politeness that is natural to him, and that regard " which he knew to be due to one whom Mr. " Watt called his intimate friend. At dinner, in " company of several gentlemen well known to " men of science, I spoke of Mr. Watt's discoveries " respecting the management of steam, and of his " intention of availing himself of them for im- " proving the steam-engine, under the protection " of a patent. Mr. Boulton joined in praising Mr. " Watt's ingenuity. After dinner, Mr. Boulton " kindly took me through those parts of his mag- " nificent works that I had not yet seen. As we " walked through a yard, he drew me aside and " said, ' Does Mr. Watt seriously mean to apply " ' for a patent?' I answered, ' Yes, most cer- " ' tainly, in conjunction with Dr. Roebuck.' " ' Why, then,' said he, ' I will stop that work;' " pointing to some brick pillars which lay on the " other side of a large water-course or ditch:—' I " ' am about erecting a steam-engine, very unlike " ' what you described, but where I should have " ' availed myself of what I learned from Mr. " ' Watt's conversation:—but this would not be " ' right without his consent.' Are these the men " who would pilfer the inventions of others?"

From another notice of Mr. Boulton, by one who had been well acquainted with his life, we extract

the following brief but emphatic summary of its principal features:—"Magnificent in his manufacturing establishments, and noble in his reception of ingenious and celebrated men of all countries, he dignified the character of the British manufacturer. The variety of his talents was only equalled by his liberality in the promotion of every useful art; and the pure honour and integrity which marked his commercial transactions added a lustre to his general worth." Mr. Boulton was born in 1728,—(the year, as he used characteristically to observe, which expresses the number of square inches in a cubic foot; and which was also that in which Sir Isaac Newton died);—and he died in 1809.*

Of Dr. William Small, whose family name is, perhaps, best known in the annals of science by his brother Dr. Robert Small's learned "Account of the Astronomical Discoveries of Kepler," we have few particulars to record beyond those which the correspondence now published will supply. But his early death has been commemorated and lamented by the pens of Keir, of Day, and of Darwin; and all the scattered notices that we have been able to collect attest the greatness of his talents and his worth. A native of Scotland, he was born in 1734 at Carmylie in the county of Angus, of which parish his father was minister; one of his ancestors being Mr. Thomas Small of Corrihall, whose armorial bearings were registered in the Lyon Office about 1680. Having been ap-

* See Translation of Arago's Eloge of Watt, p. 74, *note*, ed. 1839.

pointed Professor of mathematics and natural philosophy in the college of Williamsburgh in Virginia, he settled there for some years, and practised with great success as a physician; but coming home on account of his health and some business, he "preferred settling at home to returning to "Virginia, as he never kept his health there." He was introduced to Mr. Boulton in 1765 (the year, we need scarcely repeat, in which Mr. Watt made his memorable discovery of the separate condenser), by a letter from no less eminent a person than Benjamin Franklin; in which he is described as "one who is both an ingenious philo- "sopher, and a most worthy, honest man." "He "is," adds another of his friends in writing from London to Mr. Boulton, to announce his arrival in England, "a gentleman of great worth, integrity, "and honour; and in the way of his profession he "has the best recommendations of our most emi- "nent physicians here." To the same effect is Mr. Keir's account of him, as "a gentleman of "very uncommon merit," possessed of singular accuracy of ideas, and great acquaintance with men and things; "who, to the most extensive, "various, and accurate knowledge in the sciences, "in literature, and in life, joined engaging man- "ners, a most exact conduct, a liberality of senti- "ment, and an enlightened humanity; being a "great master in the exact sciences, and seeming "to carry their regularity and precision into his "reasonings and opinions on all other subjects." *

* Keir's "Account of the Life and Writings of Thomas Day, Esq.," 1791, p. 111, *note*.

And in a MS. note on our copy of the work from which our last quotation is taken, and which was presented by its author to Mr. Seward, its former possessor has added;—"He had, I think, the "greatest variety, as well as the greatest accuracy "of knowledge, that I have ever met with in any "one man."

It does not exactly appear whether Mr. Watt had ever met him previous to their acquaintance at Birmingham and Soho in 1767; but in age they were nearly coevals, and their correspondence shows how entire was their community of sentiment, and how similar the course of their favourite pursuits.

The happy companionship of which Mr. Watt's new association opened up a prospect to those congenial spirits, was, alas! but too evanescent. In many of Dr. Small's letters he complains of feelings of languor and melancholy, which betokened an undue failure of vigorous health: "*nil admirari*," says Mr. Keir, "was his favourite motto; which, "however, he afterwards, as his health and spirits "declined, changed to one of a darker cast, μὴ "φῦναι, the two first words of a line of Euripides,*

* Not from the celebrated speech of Jason in the Medea—

"Δεῖ μ' ὡς ἔοικε, μὴ κακὸν φῦναι λέγειν,"—

Eur. Med., l. 522.

but from one of the fragments of the Bellerophon—

"Ἐγὼ τὸ μὲν δὴ πανταχοῦ θρυλλούμενον
"Κράτιστον εἶναι φημι, μὴ φῦναι βροτῷ."

Eur. Fragm. Belleroph., xvi. 2; vol. ii. p. 432, ed. Lips., 1779.

It will be seen that Mr. Keir, when he placed the words *first* in the line, evidently spoke without referring to his author.

" expressing that it would have been better not to " have been born." And the same spring which was to witness the triumphant passing of the Act of Parliament extending the duration of the patent of 1769, beheld the languishing illness and premature death of that able, zealous, and amiable friend whose exertions had so greatly contributed to the establishment of the Soho steam-engine partnership. Early in 1775 he was seized with the symptoms of an ague to which he had previously been subject, and which did not at first appear to threaten an illness of more than common severity; but the disease proved to be a continued fever, which, notwithstanding every aid of medical skill, terminated fatally. He died on the 25th of February, having remained sensible to the last, and almost to the last having entertained hopes of his own recovery. At the time of his decease Mr. Watt was unavoidably absent, at Broseley in Shropshire, on business connected with the engine; but Dr. Ash and Dr. Darwin, with both of whom Dr. Small had always lived on terms of the greatest intimacy, Mr. Boulton, Mr. Keir, and other attached friends, constantly attended him in his last illness.

Mr. Keir has regretted, to a certain extent not without reason, that " Dr. Small, although pos- " sessed of various and eminent talents to instruct " mankind, has left no trace behind of all that " store of knowledge and observation which he had " acquired, and from which his friends never left " him without drawing fresh information." But the

panegyric is not small which he pronounces, when he adds;—" He lives only in the memory of those " friends who knew his worth, and of the poor, " whom his humane skill was ever ready to rescue " from disease and pain." " It is needless," writes the same gentleman in announcing his death to his brother, the Rev. Robert Small of Dundee, " to " say how universally he is lamented; for no man " ever enjoyed or deserved more the esteem of " mankind. Mr. Boulton and myself, who were " more particularly blest with his intimacy and " friendship, are struck with a grief suitable to " the loss which we have sustained, and which we " know can never be repaired. We loved him " with the tenderest affection, and shall ever " revere his memory." " His numberless virtues," says Mr. Boulton, " I should be happy to fall heir " to, they being the only legacy that could recon- " cile me to his death." " Messrs. Keir, Darwin, " Day, and self," adds Mr. Boulton at a later date, " have never yet agreed about a monument for " the church; but as there is nothing which I " wish to fix in my mind so permanently as the " remembrance of my dear departed friend, I did " not delay to erect one to his memory in the " prettiest but most obscure part of my garden; a " part that is modelled, at least characterised, since " you were here. 'Tis a sepulchred grove, in " which is a building adapted for contemplation; " from one of its windows, under a Gothic arch " formed by trees, you see the church in which he

"was interred,* and no other object whatsoever "except the monument. It is a sarcophagus "standing upon a pedestal, on which is written

M: S:
Gulielmi Small, M.D.
Ob. Feb. XXV.
MDCCLXXV.

"and upon the pedestal are inscribed some verses "written by Dr. Darwin, a copy of which, with a "slight sketch of the view from one of the win- "dows of the building, I herewith send you;—

"Ye gay and young, who, thoughtless of your doom,
Shun the disgustful mansions of the dead,
Where Melancholy broods o'er many a tomb
Mould'ring beneath the yew's unwholesome shade;

"If chance ye enter these sequester'd groves,
And day's bright sunshine for a while forego,
O leave to Folly's cheek the laughs and loves,
And give one hour to philosophic woe!

"Here, while no titled dust, no sainted bone,
No lover bending over beauty's bier,
No warrior frowning in historic stone,
Extorts your praises or requests your tear;

"Cold Contemplation leans her aching head,
On human woe her steady eye she turns,
Waves her meek hand, and sighs for Science dead,
For Science, Virtue, and for SMALL she mourns."

Mr. Day also, who had hastened to England from Brussels as soon as he heard of the severe illness of his friend (although unfortunately too late to be present with him in his last hour), and whose mind was long in recovering from the

* That of St. Philip, Birmingham.

gloom caused by the loss of one whom he had always venerated as a wise and faithful instructor, composed the following epitaph on his "guide, "philosopher, and friend:"—

"Beyond the rage of Time, or Fortune's power,
Remain, cold stone! remain, and mark the hour
When all the noblest gifts which Heaven e'er gave
Were centred in a dark, untimely grave.

"O taught on reason's boldest wings to rise,
And catch each glimmering of the opening skies!
O gentle bosom! O unsullied mind!
O friend to truth, to virtue, and mankind!
Thy dear remains we trust to this sad shrine,
Secure to feel no second loss like thine!" *

Dr. Small was only one of many kindred spirits, all devoted to the pursuit of natural knowledge, and filled with mutual esteem and affection, who in that neighbourhood, both then and at a later period, found profitable pleasure in each other's society. Besides Mr. Watt and Mr. Boulton, there were among that number Dr. Darwin, Dr. Withering, Mr. Keir, Mr. Galton, Mr. Edgeworth, and Dr.

* "Account of the Life and Writings of Thomas Day, Esq.," (by Mr. Keir,) p. 93. 1791.

The "sepulchred grove" of Soho has fallen; the "sarcophagus" —or, rather, *cenotaph*—has perished; and the romantic grounds surrounding Mr. Boulton's mansion, with their woods and waters, little more than a century ago an unpeopled and uncultured waste, then transformed into a series of smiling gardens and shaded lawns, have now become the site of other houses, multiplying in proportion to the immense development of the steam-engine and its results in that central and busy district of our great manufacturing country. But not so soon will be forgotten the refinement of mind, the ardour in scientific pursuits, the community of sentiments, and the warmth of friendship which long cheered those scenes with their sunshine, and seem still to visit them with a distant gleam.

Priestley;—all of them luminaries not unworthy to revolve round Watt as their central sun, but also shining with more than merely reflected light. Priestley, who came to reside at Birmingham in 1780, and has repeatedly acknowledged the happiness he experienced in living near Mr. Watt, has thus noticed those monthly repasts of which his philosophical friends and himself partook at their respective houses in turn, and which became well known as the meetings of *the Lunar Society*. "I "consider my settlement at Birmingham as the "happiest event in my life; being highly favour- "able to every object I had in view, philosophical "or theological. In the former respect I had the "convenience of good workmen of every kind, "and the society of persons eminent for their "knowledge of chemistry; particularly Mr. Watt, "Mr. Keir, and Dr. Withering. These, with Mr. "Boulton and Dr. Darwin, who soon left us "by removing from Lichfield to Derby, Mr. Gal- "ton, and afterwards Mr. Johnson of Kenil- "worth and myself, dined together every month, "calling ourselves *the Lunar Society*, because the "time of our meeting was near the full-moon,"* "in order," as he elsewhere says, "to have the "benefit of its light in returning home." From an invitation from Mr. Watt to Mr. Wedgwood to attend one of the dinners of the society, we learn that it was customary for the philosophic *convives* "to dine at two o'clock, and not to part till eight "in the evening."

* Memoirs of Dr. Priestley, by himself, p. 97. 1806.

Mr. Watt, in writing to Dr. Darwin to remind him of his engagement to attend another of those friendly meetings, at once social and scientific, gives a lively bill of fare of the subjects proposed for the consideration of the party;—some expressions used in which, viz., "it is to be determined "whether or not heat is a compound of phlogiston "and empyreal air," "what light is made of, "and also how to make it,"* as well as the still more curious ones of Darwin's reply, "I can tell "you some secrets in return for yours, viz., that "atmospheric gas is composed of light and the "earth of water (aqueous earth),—*that water "is composed of aqueous gas, which is displaced from "its earth by oil of vitriol*,"†—may be held to have foreshadowed, with more or less distinctness, those researches which ended in the discovery of "what "water is made of," and also, as the discoverer quaintly expresses it, "how to make it."‡ Thus to Darwin, the general design of whose somewhat fantastic but often elegant poetry was, as he informs us, "to enlist Imagination under the ban-"ners of Science," may now be assigned some of the merit of having been a pioneer in the march towards that great discovery:—a merit, however, which he never claimed for himself, both he and Mr. Watt having apparently given, at the time, no

* Mr. Watt to Dr. Darwin, Birmingham, January 3rd, 1781; No. [184], vol. ii. p. 128, *infra*.

† Dr. Darwin to Mr. Watt, Jan. 6, 1781; No. [185], vol. ii. p. 124, *infra*.

‡ Mr. Watt to Mr. Fry of Bristol, Correspondence of Watt on the Composition of Water, p. 24.

more than a passing attention to the "shot" thus fired, probably at random, but with a curious approximation to the mark which was afterwards effectually hit. For the speculation,—whether we call it imagination or science,—that water was a composite body at all;—that it was, in any way, composed of a "gas;"—which gas was "aqueous, "displaced from its earth by oil of vitriol," (a wonderfully fair description of the hydrogen of later days), was, no doubt, a "secret" worth communicating, even though nothing was said either of another gas, or of explosion by an electric spark. It is indeed difficult to judge how far it may not have been one of those early seeds of the great discovery, which, afterwards germinating in the sagacious mind of Mr. Watt, bore their first-fruits in his celebrated conclusions communicated to Dr. Priestley and the Royal Society in 1783; and which were afterwards followed by the second and third harvests which Cavendish and Lavoisier respectively reaped,—or *gleaned*.

That Darwin never dreamt of claiming for himself, on the strength of such expressions, any share of the credit of the real discovery as to the compound nature of water, and its true constituents, appears from his poem, "The Botanic Garden;" where, after describing the process of the formation of that fluid,—

> "Nymphs! your bright squadrons watch with chemic eyes
> "The cold elastic vapours as they rise;
> "With playful force arrest them as they pass,
> "And to pure AIR betroth the *flaming* GAS:"—

he only says,—"Until very lately, water was

" esteemed a simple element, nor are all the most " celebrated chemists of Europe yet converts to the " new opinion of its decomposition. M. Lavoisier " and others of the French school have most ingeni- " ously endeavoured to show that water consists " of pure air, called by them oxygen, and of in- " flammable air, called hydrogen, with as much of " the matter of heat, or calorique, as is necessary " to preserve them in the form of gas;" and he mentions that " The history of the progress of this " great discovery is detailed in the Memoirs of " the Royal Academy [of Sciences] for 1781, and " the experimental proofs of it are delivered in " Lavoisier's Elements of Chemistry. The results " of which are that water consists of eighty-five " parts, by weight, of oxygen, and fifteen parts, by " weight, of hydrogen, with a sufficient quantity of " calorique."* And again in a subsequent note, where, speaking of " the present important disco- " very of the production of water from pure air, " or oxygen, and inflammable air, or hydrogen," he says that one might be tempted to believe, from allegorical interpretations of the old mythology, " that the very ancient chemists of Egypt had " discovered the composition of water, and repre- " sented it in their hieroglyphic figures before the " invention of letters."† The subject is also referred to in another of Dr. Darwin's works, viz., his ' Phytologia;' where he says, " According to

* " Botanic Garden," part i. canto iii. l. 200–204; and note, vol. i. p. 152, ed. 1799.

† Ibid., p. 156, note.

" the theory of M. Lavoisier concerning the com-
" position and decomposition of water, there would
" seem another source of thunder-showers; and
" that is, that the two gases termed oxygen gas or
" vital air, and hydrogen gas or inflammable air,
" may exist in the summer atmosphere in a state
" of mixture, but not of combination; and that the
" electric spark, or flash of lightning, may combine
" them, and produce water instantaneously."* But nowhere does the highly imaginative and well-informed Doctor appear to have sought to associate his own name with the discovery on which he bestows such deserved admiration; and, indeed, the "composition" of which he writes, whatever may have been the force or the weakness of the impression which the idea of it had made on his mind, must be viewed as rather a transmigration from one substance into another, than as a compounding of two substances into one. Still, the "secret" he announces will be considered as no uninteresting addition to the literature of the late "water controversy;" *valeat quantum valere potest.*

As for the Lunar Society,† the last particular notice we have been able to find of that amicable association occurs in a dedication by Priestley, in 1793, (which was two years after his retirement

* "Phytologia, or the Philosophy of Agriculture and Gardening," p. 313, ed. 1800.

† For another friendly but brief allusion to the same Society, see Priestley's letter to Messrs. Boulton and Watt, 17 October, 1801, No. [335.] vol. ii. p. 277, *infra.*

from Birmingham), of one of his works,* to his "valued friends, the members of the Lunar Society "at Birmingham;" in which he says, "There are "few things that I more regret, in consequence of "my removal from Birmingham, than the loss of "your society. It both encouraged and enlight-"ened me; so that what I did there of a philoso-"phical kind ought in justice to be attributed "almost as much to you as to myself. From our "cheerful meetings I never absented myself volun-"tarily, and from my pleasing recollection they "will never be absent. Should the cause of our "separation make it necessary for me to remove to "a still greater distance from you, I shall only "think the more, and with the more regret, of "our past interviews." "Philosophy," he adds, "engrossed us wholly. Politicians may think "there are no objects of any consequence besides "those which immediately interest *them*. But "objects far superior to any of which they have "an idea engaged our attention, and the discussion "of them was accompanied with a satisfaction to "which they are strangers. Happy would it be "for the world if their pursuits were as tranquil, "and their projects as innocent, and as friendly to "the best interests of mankind, as ours." Finally, he concludes by earnestly committing them all, though in religious persuasion differing from him-self, "to the protection and blessing of that Great "Being, *whose we are, and whom*, I trust," he says,

* "Experiments on the Generation of Air from Water," London, 1793.

" *we all serve*; and who established that course of " nature which is the object of our common investi- " gation;" and then he prays, " with the greatest " esteem and affection," for a happy reunion with them all in another state of being.

Would to God that the fervent pursuit of science had in all cases the effect of producing a temper of mind equally calm, equally devout, and therefore equally happy!

CHAPTER X.

OFFERS OF EMPLOYMENT IN RUSSIA — VISITS TO CORNWALL — INTRODUCTION OF THE NEW STEAM-ENGINES — SUCCESSIVE PATENTS FOR NEW IMPROVEMENTS, COPYING-MACHINE, ETC. — DISCOVERY OF THE COMPOSITION OF WATER — GENERAL RESULT OF THE CONTROVERSY ON THAT SUBJECT — DINNERS AT CAVENDISH'S, AND AT THE CLUB OF THE ROYAL SOCIETY.

IN such society, congenial to all his favourite pursuits, for the next quarter of a century after the commencement of the partnership which had been thus so happily formed, Mr. Watt's life was usually passed. In the spring of 1775 an offer was made to him of employment in Russia, under the Imperial Government, which, at a somewhat earlier period, might probably have met with his thankful acceptance; for the salary promised was 1000*l.* per annum, and the duties required would have suited well his own inclinations and acquirements. The offer of the appointment in question, however, seems to have been ensured by, if it did not originate in, Mr. Boulton "having sounded "his praises at the Ambassador's;" * and he

* In 1773 Mr. Watt had an invitation from his friend Robison to come to Russia, "where he had recommended him to fill some

naturally preferred continuing with him those endeavours for a parliamentary prolongation of his first patent, on which their future association was to depend. The case also of a Captain Perry, (who, after having been engaged by Peter the Great as an engineer, and having served for many years in that country, had been obliged to take refuge in the house of the British Ambassador, and to return to England without receiving his pay), as well as representations of other similar instances, alarmed him for the consequences which might possibly again attend such despotic predilections; and recommended to his mind the less dazzling, but more secure destiny, of "a crust of "bread and liberty."

He resided chiefly near the great manufacturing establishment to which his attention was now energetically devoted; but was sometimes compelled to be absent, for long periods, in the mining districts of Cornwall,—a poor exchange, in his opinion, for the intellectual pleasures and hospitable sociality of the neighbourhood of Soho. His employments, during those intervals of forced

"station;" not probably, however, of equal value with that afterwards offered to him.

It is rather a singular circumstance, that when, in 1816, his Imperial Highness the Grand Duke Nicholas of Russia, (the present Czar), applied at the Soho works for permission to view their interior, his application, although supported by a letter from Lord Sidmouth, was rejected. The objection felt, however, was not by any means to the potentate himself or his immediate friends, but to certain persons who followed in his suite, and whom there were good reasons for not initiating into the various processes of the manufacture.

absence, were, to a great extent, neither easy nor agreeable. He had, in the first place, to push into notice and use his great invention; in doing which he had to contend not only with such obstacles as nature presented, in the dark abysses of desperately-flooded mines, but also with the deeply-rooted prejudices of a rude and obstinate class of men, generally as incredulous of the powers of the new machine, as they were ignorant of the causes of the imperfections of the old ones. How little, too, the real merits of machinery were appreciated by those among whom he had to labour, appears from an amusing description he has given* of one of the first engines which he erected in Cornwall. "At present," he says, "the velocity, violence, magnitude, and "horrible noise of the engine give universal satis- "faction to all beholders, believers or not. I "have once or twice trimmed the engine to end "its stroke gently, and make less noise; but "Mr. —— cannot sleep unless it seem quite "furious, so I have left it to the engine-man. "And, by the bye, the noise serves to convey great "ideas of the power to the ignorant, who seem to "be no more taken with modest merit in an en- "gine than in a man." Naturally disinclined to solicitation, and averse to the coarse tumult of commercial business when conducted with inferior and illiberal minds, he was expected to obtain orders and extend connections; as well as to take

* In a letter to Mr. Boulton from Truro, without date.

charge, (as he did with much greater readiness), of the erection of the new engines, and of making experiments on all sorts of old ones. In public discussions at the meetings of mining adventurers, his arguments, founded on reason and science, too often met with jarring opposition,—sometimes even with ignorant contempt;—in private he had "con-" stant bad headaches," and his "usual tendency "towards desponding views." As business increased, so did his troubles: "excessive difficulty "in finding intelligent managing clerks;"—"con-" tinual anxiety," (and frequent failure), "to get "the various parts of the metal-work executed "exactly according to his own drawings," which, it is needless to say, were made with laborious accuracy and clearness; so that, "almost distracted "with multiplicity of orders," he sometimes fancied, he said, that he "must be cut in pieces, and "a portion sent to every tribe in Israel!" Then, as soon as the real value of the new engines began to be at all understood,—as soon as that water which was reckoned the "heaviest" in the whole county, and which the sapient among the miners had, in the profundity of their wisdom, declared would never be "forked," not only was "forked," but showed, by the manner in which that process was accomplished, that the new engine "might "fork anything,"– to all his previous labours was added that hateful one of having to observe and restrain the piracies which forthwith began to be practised, secretly at first, but soon with greater frequency and daring.

The bare and miserable aspect of the country in

which his head-quarters were at such times most commonly fixed, increased the gloom of the months he was compelled to spend there; the "dismal "weather did not tend to raise his spirits;" those wilds, he says, might be defined "a tract of hills "without dales," where the roads went "straight "up the hills without flinching," and where,—(the force of savage misery could no further go!)— "*the enginemen actually eat the grease for the en-* "*gine!*" Some of his letters indeed remind one, although, of course, in all the sobriety of engineering prose, of the strains in which Ovid bewailed his exile to the remote and savage Pontus. But as the Muse did not cease, amid the horrors of barbarian skies, to cheer with her smiles the lonely hours of the expatriated Roman poet, so the genius of invention did not forsake her favourite son in his Cornish solitude, and even his '*Tristia*' give token of her inspiration.

The copper companies becoming bankrupt, or, at least, insolvent, in rapid succession, and many of the mines being already unworkable from the increase of water, while the low price of copper would not admit of the removal of that obstacle by the old and expensive means, were all circumstances which, however unpropitious at first sight, really proved advantageous to the cause of the new steam-engine, by compelling the adoption of every principle by which economy of fuel and labour could be attained. And with Mr. Watt, the whole of the period of which we are now speaking, whether passed by him at Birmingham, in Cornwall, or elsewhere, was one of the most varying and active

exertion, and the most profusely fertile in mechanical invention, of the whole of his life. This may be said to have been the case more especially as regards the first ten years of the time in question, viz., from 1775 to 1785, during which he secured, by five several patents, those almost innumerable improvements on the steam-engine, of infinite ingenuity and value, which he had made subsequent to that of the separate condenser, together with the machine for copying letters and drawings; besides originating other contrivances, which, although not deemed by him worthy of being included in patents, might have made both the fortune and the repute of many a minor adventurer in that line.

He had, at the same time, the further honourable distinction of making and publishing his famous discovery of the Composition of Water. It must be added, though we do so with regret, that, as in his greatest mechanical inventions, so in this matter also, he experienced the unpleasant necessity of vindicating his own just claims from the unexpected, and, as we believe, most men will be of opinion, the unjustifiable, interference of others. It was an occasion, however, on which the firmness, moderation, and true greatness of his mind were signally manifested; and the circumstances of which, as displayed in his Correspondence on the subject,* have contributed in every way to increase his good name.

* A publication already referred to; see note on p. vii. *supra*.

The history of that great discovery, after having received the most full elucidation and discussion, seems to have now left no just or reasonable doubt that Watt preceded Cavendish, as Cavendish preceded Lavoisier. Such is the general result into which the late controversy on the subject may be said to have subsided; as, however averse the admirers of Cavendish naturally felt, at first, to resign any portion of what they had been in the habit of regarding as his own prescriptive domains, or uneasy at anything that seemed to question his independence and good faith in the transaction by which he acquired his title to their temporary enjoyment, it is only one or two of the most hardy or litigious of their number who will now venture to maintain that the antiquity of his possession could, by any stretch of the evidence, be held to exclude the prior title of Watt.

Such a result no longer rests only on the decision pronounced by M. Arago and Lord Brougham, whose learned labours had early and carefully investigated the important documents more lately given to the world.

M. Dumas (who, it will be remembered, had, in 1840, declared that he adopted completely, and in all its parts, M. Arago's history of the discovery, and was so strongly convinced of its justness that he desired that his declaration to that effect should be recorded in the authoritative organ of the Academy of Sciences), when in England, in 1847, on a mission from his Government, came forward

to state that he had only been confirmed in the opinion which he had put on record some years previously by the consideration of all that had since been published on *both* sides of the question. And he added, that in the correspondence and other manuscripts on the subject of the composition of water, which he had occasion to study attentively with a view to that full account of Lavoisier's life and works which he is now preparing,—and which, we may observe, the scientific world has long been eagerly expecting,—he had found "strong additional reasons for awarding the "whole glory of that great discovery to Watt." *

Nor was the acceptance with which such views were received confined to those who had previously espoused the cause of Watt, or who had remained without preoccupation on the subject. As an instance of the change which was wrought by the force of truth on the convictions of others equally distinguished, we may mention a most eminent philosopher, who having, at a former period, on the imperfect information then open to him, been disposed to support the claims of Cavendish, on fully studying the fresh evidence which the correspondence of Mr. Watt first made public, unhesitatingly professed his entire conversion; and in one of those eloquent essays by which he has so often adorned the progress of scientific discovery, publicly announced, as the conclusion at which he had arrived, that the argu-

* Edinburgh Review for January, 1843, vol. lxxxvii. p. 85.

ment for Mr. Watt's priority "had now been "placed on a sound and impregnable basis." * That the name of Sir David Brewster should be known throughout the whole civilised world by the most brilliant discoveries in the most beautiful of sciences, can scarcely be deemed more honourable to him as a man, than the perfect candour which he thus displayed; and such unreserved testimony, spontaneously borne under such circumstances by such an authority, has evidently a most conclusive bearing on the question in regard to which it was delivered.

After the appearance of Sir David's fervent and powerful appeal, another eminent person, the late lamented Lord Jeffrey, consecrated the last, and we believe the longest, as it certainly is one of the very ablest of all his critical labours, to an admirable and truly judicial review of the whole controversy, then well-nigh its close.† His Lordship had, in 1819, penned the first and best eulogium that appeared on the occasion of the death of his venerated friend, "the inventor of our "present steam-engine;" and both of those works of love and respect to the memory of one whom he always delighted to honour, will long survive, as graceful memorials of their mutual fame, and of his unfailing affection. We need scarcely add that Lord Jeffrey was conducted, by his full examination of every argument used on either side of the case, to the conclusion

* North British Review for January, 1847, vol. vi. p. 497.

† Edinburgh Review for January, 1848, vol. lxxxvii. pp. 67–137.

that Mr. Watt was clearly the first original and complete discoverer of the compound nature of water; and that Cavendish never ventured to state his own theory until he had become acquainted with the discovery first committed to writing and publicly stated by Watt.

Lastly, Liebig, to whom the world is under obligations which it is almost impossible to overrate, for his application of chemical science to purposes of utility in many departments of practical life, in his 'Letters on Chemistry,' (adopting a similar view to that taken by Sir Humphry Davy, of the mere observation of a fact by Cavendish, but of its just interpretation by Watt), says that "we value facts because of their per-
"manence and immutability, and because they
"supply the soil for ideas; but *a fact acquires its*
"*true and full value only through the idea which is*
"*developed by it.* Many facts were not in the
"possession of Stahl, but the idea is his property.
"Cavendish and Watt both discovered the com-
"position of water: *Cavendish established the facts,*
"*Watt the idea.* Cavendish says, 'From inflam-
"'mable and dephlogisticated air water is pro-
"'duced.' Watt says, 'Water consists or is com-
"'posed of inflammable and dephlogisticated air.'
"Between these forms of expression there is a
"wide difference."

Already, in the course of the controversy, all has been done that seemed essential for the fame of Mr. Watt, or that was requisite for a compliance with his own simple and memorable injunc-

tion, delivered more than sixty years ago:*— "Preserve the dignity of a philosopher and his- "torian; relate the facts, and leave posterity to "judge." And the course which the opinion of that tribunal has thus taken, relieves us from the necessity of further considering the arguments,— if, indeed, they deserve the name of arguments,— which have been offered by the professed partisans of Cavendish; the success of whom, as controversialists, is understood to have been in a direct ratio to the smallness of their number, though, (it has been somewhat maliciously observed), in an inverse one to the largeness of their pretensions.

For, on the present occasion, we can afford to exclude from the list of those judges to whom Mr. Watt's appeal was made, all of those learned persons, such as Maty, Nicholson, Thomson, Murray, Dalton, and others, who have with propriety been referred to as having, during the lifetime of both Watt and Cavendish, or of one of them, assigned the priority to the former. But when of those who have spoken since the death of both claimants we find one great name after another,—DAVY, and HENRY, and ARAGO, and BROUGHAM, and DUMAS, and BERZELIUS, and BREWSTER, and JEFFREY, and LIEBIG,—illustrious umpires of more than European fame, devoted to various pursuits, scientific, legal, and literary, and whose judgments are destined to an enduring celebrity,—all deciding in favour of the priority of

* To Dr. Darwin, 24 November, 1789, No. [300.] vol. ii. p. 236, *infra*.

Watt over Cavendish; when we find on the other side, (to adopt Lord Jeffrey's estimate and account of them), "*only Harcourt, Peacock, and Whewell;*"* and when we further recollect how vastly greater is the disproportion of scientific and judicial weight attaching to those two sets of names respectively, than even that which exists between their very disproportionate numbers; we feel that the decision to which The First Discoverer looked forward with sure and tranquil confidence, has at length emphatically been pronounced; that in the even hand of Justice the balance has at last descended; that Truth *is* great, and *has* prevailed over both the natural prejudices and prepossessions of time, and the less excusable bigotry of partizanship. And as, in the wonderful history of elemental Nature, by NEWTON, "*Qui genus humanum* "*ingenio superavit,*" first was developed the mag-

* With these should, perhaps, be classed Dr. G. Wilson, in his 'Life of Cavendish' for the Cavendish Society; a work in which, having undertaken to defend the conduct of both Cavendish and his aide-de-camp Blagden, as well as endeavoured to recover for the former his lost priority, he has been thereby betrayed into some very diffuse and not very profitable wrangling. But the learned Doctor, while he thinks that unanimity of opinion in reference to many of the points which he disputes cannot be expected, and should not be demanded, has also the fairness to admit that the date of Cavendish drawing his inference as to the elements of water cannot with certainty or precision be fixed at an earlier period than the *summer* of 1783, (Mr. Watt having, we may remind the reader, made his known in *April of that year*); that he himself believes that Cavendish's views on the subject "altered "and expanded from 1781 onwards *to* 1784," (when they were first published); and that, at all events, "there can be no doubt that Mr. "Watt's theory increased the faith of Cavendish and Lavoisier in their "own views, and won the approval of the great majority of their "scientific contemporaries," &c. &c.

nificent idea of the COMPOSITION OF LIGHT, so it may safely be recorded that to WATT, the great subjugator of the power of steam, first occurred, and by him was first set forth, the no less novel, astonishing, and fruitful idea of the COMPOSITION OF WATER.

With one parting admonition we conclude all that it appears needful now to say on this subject. Dr. Faraday, unquestionably the most illustrious living representative of the chemical science of Great Britain, while he laments that "in the pre-" sent day there is no lack of cases amongst " philosophers in which men poach on the ground " preoccupied by others," expresses his hopes that " this case, as it now stands forth, will be a warn-" ing to some ; and assist in reviving and restoring " the moral and honourable feelings of those who " may, by circumstances, come hereafter into " temptation." * A sentiment in which all true lovers of science, who desire to be no less just than they are wise and learned, will cordially concur, and which we commend to the attention of all others whom in a different way it may concern.

It may somewhat relieve the dullness of scientific discussion, and also present a more cheerful view of human nature than some other parts of " the water controversy " afford, if we offer such confirmation as our present researches enable us

* From a MS. letter of Dr. Faraday to the Editor, who has been kindly authorized in this manner to make its contents public.

to do, of the late Mr. James Watt's assertion that his father, "after becoming in 1785 a Fellow of "the Royal Society, formed the personal acquaint- "ance of Mr. Cavendish, and lived upon good "terms with him." * In August of that year, it appears, Cavendish visited Birmingham and Soho, where he spent some time in examining the engine establishment, and conversing with Mr. Watt upon it:—and in October of the same year, Mr. W. wrote † as follows:—"When I was in "London I was received very kindly by Mr. "Cavendish and Dr. Blagden, and my old friend "Smeaton, who has now recovered his health, and "seems hearty. I dined at a turtle feast with "them and the select club of the Royal Society; "and never was turtle eaten with greater sobriety "and temperance, or more good fellowship. I "dined also at Mr. Cavendish's, who lives very "elegantly, and gave us a good English dinner. "Among other company we had the famous "Peter Camper, the Anatomist, once Professor at "Franecker, ‡ a fresh gigantic man of 64, that "never had sickness in his life except once. He is "to come here before leaving England." §

* Correspondence of Mr. Watt on his Discovery of the Composition of Water, p. iv.

† To Mrs. Watt, Birmingham, October 31st, 1785.

‡ In Friesland. Camper was born in 1722, and, in the same year in which he met Mr. Watt, was elected a member of the Academy of Sciences at Paris. He died in 1789; and is buried in St. Peter's Church, Leyden.

§ Which he accordingly did: as we learn from a letter of Mr. Watt to Mrs. Watt, dated Birmingham, November 3, 1785—"I had a visit of "Professor Camper yesterday: he is a fine old fellow."

Notwithstanding the epithet here applied by the guest,—a man of plain habits and simple tastes,—to the style of living practised at Cavendish's house, the hospitalities of that abode are admitted, even by the panegyrists of its master, to have been neither numerous nor profuse. The "good English "dinner" was probably the eternal *leg of mutton*, which, on days of unwonted festivity, made the cheer at that table of hungry science; but which, on one extraordinary occasion, when the company amounted to *six*, was known to have been multiplied by two, and thus to have formed a repast of legs of mutton,—like rainbows,—primary and secondary. We must regret that neither Mr. Watt, nor, so far as we know, any one else, has left any record of Mr. Cavendish's "flow of soul" on the evening in question; but the contrast must have been a striking one, between the nervous chemical misogynist, racoon-like "uttering a shrill "cry as he shuffled quickly from room to room;" * and the thoughtful but active and animated engineer, with "voice deep and low, in harmony "with the weight and beauty of his discourse; "mirthful, temperately jocular," † and with a manner marked, beyond that of all others, by "a "fine expression of reposing strength and uninter-"rupted self-possession." ‡ We may, however, conjecture that at that interesting party the subject of the composition of water was not broached;

* Lord Brougham, "Life of Cavendish," p. 446.
† Lord Brougham, "Life of Watt," p. 389.
‡ Lord Jeffrey, "Character of Watt."

and that the "best of elements" was discussed only in undecompounded and corporeal form, befitting the sobriety of a board over which Bacchus is understood *not* to have presided as the tutelary deity.

In point of convivial enjoyment, the other dinner mentioned in Mr. Watt's letter would appear, from his expressions, considerably to have excelled the entertainment supplied at Cavendish's eremitical abode. And we are not without other means of estimating the amount of good fellowship which habitually prevailed at those "noctes "cœnæque Deûm" of the club of the Royal Society. That distinguished mineralogist, M. Faujas de St. Fond, has devoted some pages of his travels in Great Britain to recording the scene he witnessed, and the impression it made upon him, when a few years later he partook of a like hospitality; and as, on the occasion of which he speaks, Sir Joseph Banks was President, Blagden Secretary, and Cavendish one of the party, and all of those three are among the persons of what we may term the drama of the discovery of the composition of water, we perhaps need not apologise for introducing some notice of that feast of scientific reason, which M. de St. Fond has minutely, and with evident relish, described.

At this "dinner of an academic club," which commenced at five o'clock, he says, "the dishes "were of the solid kind, such as roast beef, boiled "beef, and mutton prepared in various manners,— "with abundance of potatoes and other vegetables,

" which each person seasoned as he pleased with " the different sauces which were placed upon the " table. The beef-steaks and the roast beef were " at first sufficiently drenched by *large quantities* " *of strong beer, called porter*: it was drank out of " cylindrical pewter pots, *which are, by some, thought* " *preferable to glasses, perhaps because they enable* " *one to swallow a whole pint at a draught.* This " prelude being finished," there appeared, " as if " by magic, a number of fine crystal decanters " filled with the best port, madeira, and claret." " Several glasses were distributed to each person, " and *the libations commenced on a grand scale*, in " the midst of different kinds of *cheeses, which,* " *rolling in mahogany cases from one end of the table* " *to the other, provoked the thirst of the drinkers.*" " The members of the club afterwards saluted " each other, one by one, with a glass of wine. " According to this custom, *one must drink as* " *many times as there are guests*, for it would be " thought a want of politeness in England to " drink to the health of more persons than one at " a time." M. de St. Fond had mentioned, in an earlier part of his account, that the club consisted of about forty members, each of whom had a right to introduce two, and the president a greater number of friends. He does not mention by how many the guests, and consequently the glasses of wine drank by each at this stage of the entertainment, fell short of the hundred and twenty to which that compotatory computation might amount. But, *qualis ab incepto*, the convivial

narrative proceeds :—" *A few bottles of champagne* " *soon put all the company in good humour.* The " tea came next, with butter, marmalade, and " all its usual accompaniments: coffee followed, " humbly yielding precedence to the tea, though " it be the better of the two. In France, we " commonly drink only one cup of good coffee " after dinner; in England, they drink five or six " times that quantity, of the most detestable kind. " *Brandy, rum, and some other strong liquors, closed* " *this philosophic banquet.*" And for the solid repast with all its fluid accompaniments,—" all " this intolerable deal of sack,"—each of the guests paid " seven livres, four sols French " money." With justice does the good M. Faujas remark " This was not dear;" and he sympathetically adds " The great Corneille, Molière, " Despreaux, La Fontaine, and Racine, used to " take a bottle now and then in a tavern; and " they were neither the worse friends, nor the " worse poets for it."

Science, indeed, seems, at the symposium which he thus describes, to have appeared to M. de St. Fond in that form, " quæ, si oculis cerneretur, " mirabiles amores, ut ait Plato, excitaret sapi- " entiæ!" * And, although the *sçavoir vivre* of the tavern in London may not have strictly exemplified the succulent doctrines of the " Alma- " nach des Gourmands," or complied with all the gustatory directions of the " Manuel des Amphi- " tryons," yet so highly was the honest Frenchman

* Cic. De Off. I. cap. v.

delighted with the lively but decorous gaiety which he had witnessed, as to have imagined that a similar system of "convivial and modest banquets" among the learned men of his own country, might have averted some of the worst crimes of its regicidal revolution;—crimes, which the exalted but hapless names of Malesherbes, Bailly, Lavoisier, and Condorcet, recall to the horror and grief of humanity. "In France they *now* order these "things better;" and all who have enjoyed the privilege of sharing in the festive entertainments frequent among the men of letters and science in the metropolis of that great and polished nation, can bear testimony to the simple but elegant refinement, the warm-hearted hospitality, the love of the Muses and admiration of the Graces, by which they are distinguished. Let us indulge the hope, that the frequent recurrence of scenes so congenial to the wishes of M. Faujas, may ensure all those happy results which he fancied,—(perhaps not very unreasonably),—that he foresaw in their due observance!

CHAPTER XI.

MR. WATT'S JOURNEY TO PARIS AT THE REQUEST OF THE FRENCH GOVERNMENT — MACHINE OF MARLY — INFRINGEMENTS OF THE PATENTS — TRIALS AT LAW — PARTIES TO THE ACTIONS — ARGUMENTS AGAINST AND FOR THE VALIDITY OF THE PATENT OF 1769 — NATURE OF THE EVIDENCE — J. BRAMAH AND T. TREDGOLD — VERDICTS IN FAVOUR OF THE PATENTEES — VALIDITY OF THE PATENT OF 1769 CONCLUSIVELY ESTABLISHED.

In 1786, Mr. Watt and Mr. Boulton proceeded to Paris, on the invitation of the French government, to meet proposals for their erecting steam-engines in that country under an exclusive privilege. In particular, they were to suggest improvements on the great hydraulic machine of Marly; that gigantic specimen of a race of mechanical megalosaurians, now nearly extinct, of which Belidor has given a striking description, but which he introduces by the eulogy,—a very questionable one, as most of our readers know, where machinery is concerned,—" il ne paroît pas que l'on ait jamais " exécuté de machine *qui ait fait autant de bruit* " dans le monde que celle de Marly." * Although the principal objects of their visit were frustrated

* Belidor, Archit. Hydraul. Livre iii. chap. iv. vol. ii. p. 195, ed. 1739.

by the political circumstances of the time, the English engineers had the satisfaction of making the acquaintance of most of the eminent men of science of whom the great capital of France had then to boast, such as Lavoisier, La Place, Monge, Berthollet, De Prony, Hassenfratz, Fourcroy, Delessert, and others; with many of whom they afterwards maintained a friendly correspondence.

It was then that Berthollet communicated to Mr. Watt his discovery of the new method of bleaching, by means of what was then termed the dephlogisticated acid of sea-salt; and exhibited the process in the presence of a number of spectators, among whom were Mr. Watt and Mr. Boulton. On their return to England, those gentlemen mentioned to Mr. Pitt that M. Berthollet was in possession of such a process, in the view of obtaining for him a parliamentary reward, or exclusive privilege in Great Britain :—an object, however, which proved to be so difficult of attainment, that M. Berthollet subsequently renounced any lucrative views connected with his discovery, in this country. He then gave permission to Mr. Watt to communicate it to his father-in-law, Mr. Macgregor, who was enabled to employ it in his trade, along with several new improvements of Mr. Watt's invention, the results of a long series of experiments. The process was also practised on a large scale, (in consequence of similar information communicated to them by the original inventor), by Messrs. Henry, and Baker and Co.,

of Manchester; and so greatly did the new improvement succeed, that it soon afterwards appeared, on the occasion of a trial as to the validity of a patent for preparing the material used, that one bleacher at Manchester bleached at the rate of a thousand pieces of muslin (of thirty yards each) every day, and that the goods were only three days in hand until they were completely finished. Another declared that the saving of potash which he effected by using the new process, amounted to above 2000*l.* in the course of little more than a year.

But we must turn from such *délassements* as scientific feasts and philosophical tours, by which the ordinary routine of Mr. Watt's laborious life was occasionally,—but only too seldom,—pleasantly diversified, to a far less agreeable but more compulsory occupation in which a considerable portion of it was now unavoidably consumed. It has long been the hard fate of most inventors, if their inventions are of any real value, to be assailed by unworthy and surreptitious rivals; and Boulton and Watt formed no exception to the too great universality of this rule. For very many years, although seriously injured by the piratical practices of their opponents, they submitted to them, if not in silence, at least without openly punishing them by law. The consequence was, that in course of time, engines on the principle of separate condensation, and with such other particulars of the Soho construction as could be picked up by bribery of workmen and other

clandestine means, began to be erected. It is true, that of such engines, which were of very erroneous proportions and defective manufacture, the performances were usually far from being successful. Some, like Hornblower's at Radstoke, were "obliged to stand still once every ten "minutes, to snore and snort." * Some were like Evans' mill, which "was a gentlemanly mill: it "would go when it had nothing to do, but refused "to do any work." The greatest achievement which some others succeeded in effecting, was to burst their own boiler, or break their own machinery to pieces. But the manifestation even of such energy was rare among them; of all "the "bodily presence,"—so, at least, thought Mr. Watt, —"was weak," and the work "contemptible." Still, even such imperfect and really useless machines injured the fair traders, by attracting customers through a specious though deceptive show of cheapness; while on the other hand, their numerous faults, and the annoyances which they caused, tended to excite a prejudice even against the Soho engines, which were often ignorantly classed along with them under the general category. At last, it was deemed right, as the least of two evils, to try whether the exclusive privilege could not be compulsorily and penally established against those who had infringed it; and the wide field of litigation was therefore deliberately, though reluctantly, entered upon.

* Mr. Watt to Mr. Boulton, 5th September, 1783.

The legal proceedings, both in equity and at common law, which now became necessary, were numerous; and it is painful, even at this distance of time, to contemplate the mass of litigation through which, in mere self-defence, the patentees were compelled to struggle. A bill of costs, sent in by one firm of solicitors in London, for their outlay and professional services in matters connected with the various infringements, has been preserved, and is now before us: amounting, for the short space of the four last years of the time to which the extension of the patent was limited, viz. from 1796 to 1800, to between five and six thousand pounds! This was unquestionably a fearful tax;—a burden grievous to be borne by the successful discoverer in science, and his enterprising associate, in seeking the final, though tardy, enforcement of justice!

But that pecuniary amount, large as it is, and representing, as it probably does, not much more than one half of the whole expense caused by the proceedings of their opponents, cannot for a moment be viewed as equivalent to the mental and bodily labour, the constant anxiety and frequent vexation, which such opposition entailed; all of which were aggravated, in a high degree, by the comparatively unsettled state in which the law of England then remained on the subject of patents.

It is melancholy to reflect that, in any case, that leisure and tranquillity of a philosophic mind which might have produced further discoveries of refined beauty or extensive utility, should be sacri-

ficed and consumed in resisting the invasion of the powerful, or defeating the fraudulent chicanery of the covetous. And when to this reflection is added the further and still more grievous knowledge that such resistance may not, and in the chances of human affairs cannot, always meet with success, the peculiar hardship of the lot of many a deserving person, whose genius has, unfortunately for himself, distinguished him among his fellows, will at once become apparent. Thanks to those learned and indefatigable labours in the cause of law reform in this kingdom, with which must ever be associated in honour the name of Brougham, such occurrences, instead of being the common rule, can henceforth be only the rare exception; and it is not easy to estimate the amount of benefit which has thus been obtained for the ingenious, but possibly humble, poor, and friendless inventor, by one who could alike compassionate his necessities, and sympathise with his difficult pursuit of science.

The advancing years of both Mr. Watt and Mr. Boulton, of whom the expiration of the patent found the one approaching, and the other already past, his threescore and tenth year, made them both feel more sensibly the severity of so distasteful a conflict; which, although conducted with both skill and determination on their own part, was latterly entrusted chiefly to the management of their sons, Mr. James Watt, Junr., and Mr. M. Robinson Boulton. "In the whole affair," writes Mr. Watt to his old friend, Dr. Black, "nothing

" was so grateful to me as the zeal of our friends, " and the activity of our young men, which were " unremitting."

Two trials in particular there were, in which Mr. Watt's principal invention, and the patent granted for its exercise, became the subject of full and elaborate discussion; and which, both at that time and since, attracted too much attention to be at present unnoticed by us. Our remarks, however, on this part of our subject need be few, as further information on the various points noticed in the course of the arguments delivered, whether at the bar or from the bench, will be found in the reports of the opinions of the Judges, taken in short-hand at the time, and which are given in the Appendix to this work.

In both of those causes Messrs. Boulton and Watt were the plaintiffs. The defendants were, in one of them a person of the name of Bull; and, in the other, Messrs. [Jonathan] Hornblower and Maberly. " Mr. Bull," as was mentioned by Mr. Sergeant Adair (one of the counsel for the plaintiffs), in introducing him to the notice and acquaintance of the jury at the trial, " was an officer, " — if he might dignify it by that epithet,— " known, in all places where fire is used, and to " be mended, raked, or stirred, by the name of " *a stoker.*" And by having been employed by Boulton and Watt in that honourable capacity, and afterwards as an assistant engine-tender, he gained that acquaintance with the construction of

* 15 Jan., 1797.

their engines, through which he ultimately sought to deprive them of their patent rights. The cause of "Boulton and Watt *v.* Bull," was tried in the Court of Common Pleas on the 22nd of June, 1793, by a special jury, before Lord Chief Justice Eyre. Among the witnesses on the side of the plaintiffs were De Luc, Herschel, Lind, Southern, Mylne, Cumming, Murdock, More, Rennie, and Ramsden; and when their counsel rose to reply to the evidence adduced for the defence, the foreman of the jury said that the jury were already perfectly satisfied. The verdict was for the plaintiffs, subject to the opinion of the Court as to the validity of the patent. On the 16th of May, 1795, the special case came on for judgment; when, as will be seen from the Report given in the Appendix, the opinions of the Judges were equally divided. *For* the patent were Lord Chief Justice Eyre, and Mr. Justice Rooke; *against* it, Mr. Justice Heath, and Mr. Justice Buller. Mr. Boulton, dining with the last-mentioned Judge shortly before the opinions were delivered, and having some idea of the view his Lordship was supposed to be likely to take of the points of law, gaily alludes to that learned person, when dispensing the hospitalities of his table, as "*dressing with flowers the victim he* "*is preparing to sacrifice.*" About the same time, so multifarious were the questions which the legal acumen of the counsel and Judges had raised concerning the patent and its infringement, that Mr. Watt writes, "Since I have been so much "among the doubting limbs of the law, it is

" impossible to come to a conclusion upon any " subject!"

Of the two defendants in the second cause, it was with perfect fairness stated at the trial that Mr. Maberly supplied the purse, and Mr. Hornblower the ingenuity, requisite for the infringement; and further, with a just severity, that Mr. Hornblower derived his knowledge and ingenuity undoubtedly from the most respectable source he could have derived them from, because he derived them from the ingenious inventor of the steam-engine himself, having acted for a considerable time, like Mr. Bull, in the employment of Messrs. Boulton and Watt. He was one of a numerous band of Hornblowers,—" Horners," or " Trumpeters," as they were sometimes called,—who seem to have followed mechanical and piratical pursuits under names partaking of an odd unanimity of patriarchal alliteration. There were Jonathan, and Jethro, and Jesse, and Jabez the elder, and Jabez the younger. Jonathan, an engineer, " a coppersmith," says Mr. Watt, " who, " like Alexander of that trade, hath done us " much harm;" Jethro, a working engineer; Jesse, an engineer; Jabez the elder, an engineer, the brother of Jesse, and a defendant in this action. Finally, Jabez the younger, the son of Jabez the elder; and of him the description given is, that "*he calls himself* an engineer." Of the history of those people, beyond their interference with the engines and patents of others, we know little; but it is not creditable to the prudence and

industry of that particular Hornblower who was associated with Mr. Maberly; that within a very few years after the close of the litigation, he was almost starving, a wretched prisoner in the King's Bench. Even then, his animosity against his former patrons had not ceased,—

"Still in their ashes lived his wonted fires,"

and they blazed forth in a sort of tract or memoir on the steam-engine, printed in Dr. Olinthus Gregory's Treatise on Mechanics, in 1807. That paper, although it may well appear not to have deserved any such notice, met with a crushing demolition in an article in the Edinburgh Review,* which is understood to have proceeded from the pen of Professor Playfair, and was at the time termed his *Olynthiac Oration.*

The cause of "Boulton and Watt *v.* Hornblower "and Maberly," was tried in the Common Pleas on the 16th of December, 1796, and, like the previous case, by a special jury, before Lord Chief Justice Eyre. The verdict was, again, for the plaintiffs; and the proceedings on a writ of error subsequently brought, had only the effect of affirming that result by the unanimous opinion of the four Judges before whom it was argued, (as it was most ably and fully), on two several occasions.

The arguments against the validity of the patent, offered by the defendants in the action, (the plaintiffs in error), in the Common Pleas,

* Edin. Rev., vol. xiii. p. 311—333. See also vol. ii. pp. 311—312, *infra.*

were principally drawn from alleged objections to the sufficiency of the specification of 1769. And it must here be observed that the statute continuing the benefit of the letters patent, (which, having been granted for fourteen years from the 5th of January, 1769, would otherwise have been determined, by length of time, previous to the date of the action), provided that every objection in law competent against the patent should be competent against the statute, in case the patent ought not to have been granted: on grounds, namely, of prior invention and public use, or of the specification not complying with the conditions required by the statute (21 Jac. I., cap. iii.). But for such a proviso, objections to the validity of the patent, founded on the alleged sufficiency of the specification, could not have been listened to. It was, however, contended on the part of the infringers;—

1. Generally, that the description of the engine given in the specification was not sufficient to put the public in possession of the best mode of making such engines on the newly invented principles, so as to entitle the patentee to the benefit of the monopoly, which the policy of the law prescribes shall be granted and secured only on condition of that being done.

How far this objection was or was not well founded, became, of course, matter of evidence for the jury; and while among the witnesses for the plaintiffs there was an unanimous concurrence of opinion as to the sufficiency of the description

given in the specification, even those called by the defendants were, with few exceptions, also obliged to admit it. The exceptions were some three in number, and the contrary nature of their testimony was at once accounted for, either by the interest they had, as being themselves infringers, to overthrow the patent, or by their inferior skill in their business as mechanics. On the one side were called intelligent men, who proved, that even from far less aid than was supplied in the specification, they actually had constructed steam-engines on the patented principle. On the other side, as it was well remarked at the trial, appeared "*blockheads, who swore, with* "*perfect veracity, that they could not do it!*"

A curious and interesting proof of how clearly the novel idea of condensation in a separate vessel could be presented to the mind of any one accustomed to consider mechanical subjects in a practical point of view, even when unaccompanied by anything like the fullness and clearness of the specification, was supplied by Mr. Robison in the following anecdote, which was understood at the time to have had a decisive effect on the minds of the Court and Jury:—

"In the year 1770," says Professor Robison, "I went to Russia, to take the direction of the "Imperial Academy of Marine in that country. "My house was adjoining to the bason into which "the docks of Russia were drained; the water "was drawn out by two expensive windmills; it "occurred to me that a steam-engine would an-

" swer the purpose better; and, as that country
" was at a great distance from pit-coal, it occurred
" to me that Mr. Watt's engine was the best. I
" recommended the Admiralty College to erect
" a steam-engine; this occasioned a good deal of
" conversation between me and the gentlemen
" of science in that country, particularly a Mr.
" Model, the Court apothecary, a gentleman of
" great reputation, and one of the first chemists
" of the age, whom I had instructed in the doc-
" trine of latent heat. I wrote to Mr. Watt,
" desiring him to undertake the erection of an
" engine. Mr. Watt, with that liberality which
" is natural to him, declined interfering in it.
" The expression of his letter was, 'I think you
" 'are fully able to conduct that project, and it
" 'will do you credit in the country where you
" 'are.' The day that I received this letter, I
" went to drink tea with Mr. Model; and found
" sitting with him Mr. Aepinus, a gentleman no
" less eminent for his beautiful theory of mag-
" netism and electricity. I mentioned Mr. Watt's
" genteel declinature, and also a passage of his
" letter, in which he said that by admitting steam
" to press down the piston, its want of perfect
" tightness was not so hurtful as appeared at first
" sight, because the steam which got past would
" only be lost, but would not choke the engine.
" Model broke out into an exclamation, confirming
" what I said. Aepinus did not see the force of
" what we said, and Model took out his pencil
" to make a sketch which would explain it to him.

"Not readily finding a bit of paper, I pulled a "bit out of my pocket, on which he made a sketch. "This happened to be an official report, which I "had that day received at Cronstadt, and which I "kept with many things of this kind, and they "came home with my other papers. I submit it "to the inspection of the Court, and presume it "will be acknowledged as a convincing proof that "Mr. Model completely understood Boulton and "Watt's method; and that much less information "than is given in the specification is sufficient for "enabling an intelligent engineer to erect an "effective engine, or to comprehend Mr. Watt's "principles."

2. It was objected, secondly, in particular, that the mode of condensation, (by injection of a jet of cold water), was not specified.

But as this mode was familiarly known to all engineers, and even to most common mechanics, to have been ordinarily practised in Newcomen's engines, the repetition of it by Mr. Watt in his specification was quite uncalled for; no departure from the former practice, in that particular, being intended by him to be adopted.

3. That the relative proportions which the condenser should bear to the cylinder, and which the air-pump should bear to the condenser, were not specified, so as to render it unnecessary to resort to experimental trials, in the construction of engines on the new principles.

On this head, it was readily shown that it was not requisite, according to any fair interpretation

of the law, that the specification should describe the proportions of the various parts of an engine so that any person whatsoever might, without previous instruction as an engineer, be thereby enabled at once to construct a perfect steam-engine; that it was quite sufficient if it gave the information needful for such as had both received some previous education, and had some just right to be regarded as engineers; that the exact proportions of either the condenser or the air-pump were quite immaterial to the satisfactory performance of the engine, provided only they were large enough to do the usual work of condensation and pumping; and that the magnitude proper for each of them could not fail to be known to all who possessed the amount of previous knowledge required for such business before the new invention was made.

4. That of the various substances specified to be employed instead of water, to render the piston or other parts of the engines air and steam-tight, viz. "oils, wax, resinous bodies, fat of animals, quick-"silver, and other metals in their fluid state," only one, (the fat of animals), was useful and economical in practice; and quicksilver, in particular, by corrosion and amalgamation, would injure any parts of the engine that might happen to be made of brass, to which it might get access.

There was evidently nothing in this objection deserving notice; as it was pretty certain that if any one of the substances specified was both cheapest and best, (as was said to be the case with

mutton suet), *that* would soon be adopted, to the exclusion of the rest. As for the argument from the *quicksilver*, all mechanics at all acquainted with their business knew very well that that metal ought not to be applied to any brass work; and the Chief Justice could not help observing, that so *mercurial* an objection was scarcely to be considered as a subject for grave discussion.

5. That no annexed drawing or model of the new engine was lodged with the specification.

Unfortunately, the numerous piracies that were successfully practised, showed but too forcibly, that no drawing or model was requisite to enable counterfeits of the new engine to be made. The fact was, that either drawing or model was not only quite unnecessary, and, from the endless variety of forms in which the invention might be applied, quite useless; but it might really have injured the efficacy of the patent by limiting the extent of its application. For it must always be remembered, that the invention was not, (as the infringers tried to represent it), of a new engine, but of a new method of saving fuel, by condensing the steam in a vessel apart from the cylinder. That separate condensation was the thing patented, in whatsoever form, or to whatsoever engine it might be applied; although the best mode of carrying out the principle, by valves, alternate communication, &c., was clearly pointed out, so as to be intelligible to all engineers or mechanics of ordinary capacity and education in their trade. The allegation of the defendants on this head was

also triumphantly refuted by the remarkable circumstance given in evidence by Professor Robison, which has been already cited.*

"I know," adds Professor Robison, "that it has "been repeatedly objected to this opinion of men "of science concerning the sufficiency of the specification, that Mr. Watt's own accounts are in "opposition to it. He had to encounter many "difficulties before he perfected his machine, even "after obtaining his patent. I know this well. "But this was chiefly in subordinate parts of the "undertaking. I firmly believe that the great "principles were as perfect in his mind in a few "hours, as they are at this day; and that the "physical parts of the problem were as completely "solved by his first model, as they are now by his "best engines. But when Mr. Watt was engaged "in bringing the contrivance to perfection, he "wished to perfect every part. He who wished "to make his engine not only the best, but the "cheapest in the world,—he struggled long, in "opposition to his own judgment, at Dr. Roebuck's "instance, to perform the condensation without "injection. He had a predilection for the wheel "engine, and much time and labour were spent "on it, while he was uncertain whether he "should bring this, or the reciprocating engine, "first to the market. He had experience to "acquire in great works, and in the practice of "several trades employed in such constructions.

* See pp. cxcvi.–cxcviii., *supra*.

" He had workmen to instruct, and to form; and " to keep with him, after they had acquired from " him a little knowledge, and were worth bribing " away from him. But the chief cause of the " delay was that indelible trait in Mr. Watt's " character, that every new thing that came into " his hands became a subject of serious and syste- " matic study, and terminated in some branch of " science. How rarely do we meet with such a con- " junction of science and art,—how precious when " it is found;—how much then does it deserve to " be cherished! What advantages have been " derived within these twenty years from this " fortunate union;—how much then does it become " our courts to encourage and support it against " the unprincipled attacks of ignorant and greedy " plagiarists, who would deceive our men of pro- " perty, ruin them by expensive projects which " terminate in disappointment, and thus discourage " those who alone can by their capital give any " effectual aid to the energy and genius of this " country! We boast of our Newton, and place " him at the head of our philosophers;—our " Boulton and Watt want only *justice*, and all " Europe will place them at the head of our " artists."

The originality of the invention, and its great importance to the public, were at once established by the plaintiffs; and, indeed, were admitted by the defendants. The very multitude of the infringers bore testimony to the value of the discovery; their occasional construction of tolerable engines

on the new principle proved the sufficiency of the specification; and their audacity was in proportion to the despair they felt of being able to rival, by honest means, the success of the inventor. The whole of the weight of the evidence was justly held to be in favour of the plaintiffs, on whose side were called men of the highest order of intelligence and of the greatest celebrity in physical science, as well as in the various departments of the arts:—such as De Luc, Herschel, Ramsden, Robison, Cumming, Southern, and others, most of whom, as has already been mentioned, had also given evidence in the previous case against Bull.

Among the host of opponents who, having in the first place themselves infringed the patent, were *disinterestedly* desirous, *for the benefit of the public*, that its validity should be overthrown, one of the most forward, pertinacious, and loud, was Joseph Bramah. This person, very well known for his mechanical improvements in locks, and other useful contrivances, attended as a witness on behalf of the defendants in 1796; but having on that occasion been cut short, by the Judge, in an endeavour to lay before the Court what he calls "a few remarks,"—(they extend to ninety-one printed pages!),—he at last delivered them to the public in the form of a letter to the Chief Justice, remonstrating against the verdict which had been unhesitatingly found for the plaintiffs. In the outset of this epistle, Bramah states that he was, at the trial, "much incapacitated by those "alkalescent and morbific exhalations, ever a con-

" sequence of large and close assemblies;" and the abrupt judicial syncope of his intended evidence he attributes, (no doubt justly enough), to the attention of the Court having "become flaccid " through fatigue." Proceeding in this strain, he begs leave " to recapitulate in a comprehensible " form the matter of that evidence, compounded," (he says), "with the whole substance which had " occurred to his understanding!"

The specification of the separate condenser generally, is, this excelling sage informs us, a " very abstruse and ambiguous concern:" and that of the steam-wheel, "a complete jumble of " incoherent, unconnected, absurd, and indigested " ideas; so blended *and coagulated with mystery*, " ambiguity, and impossibility in practice, that it " is a disgrace to the writer, and would un- " doubtedly *ruin any mechanic who might attempt to* " *analyse it.*"

The principle of working engines by the alternate expansion and contraction of steam, (the expansive principle added to the separate condensation), he introduces thus:—"And behold! " what does he," [Mr. Watt] " (by way of misleading), but propose what every man of chymical " science must reject, viz., to work engines by the " partial expansion and condensation of steam."

Bramah offers it as "a condensation of his own " ideas diffused through his letters," that "*all* " *kinds of condensers*, and even eduction-pipes, " on the principle of Watt's engines, *impede the* " *working of the engine*;"—and "thinks that it must

" be obvious to every one, *as it had ever been to* " *him, that Mr. Watt had really invented nothing* " *but what would do more mischief than good to the* " *public.*"

The *learned* author of the pamphlet from which these quotations have been made, complains in it of having been called in Court, at the trial, " a " fool, blockhead, shoemaker, and water-closet- " maker." If for the third of those epithets there were any foundation in fact, it would, indeed, rather appear that Mr. Bramah had too rashly disregarded the warning of the well-known Latin proverb, addressed to " criticising cobblers." But the two first terms of reproach we should be the last to apply to the author of so amusing a curiosity of literature as the pamphlet in question; furnishing as it does so sufficient a specimen of the spirit and style in which the rights of the claimants under the patent were resisted, as well as of the amount of erudition by which that resistance was audaciously supported. It was in the vexation caused by the multifarious piracies, of which Bramah's was one, that Mr. Watt was tempted, " in the " anguish of his mind," almost to " curse his inven- " tions;"—to declare that " there is nothing more " foolish than inventing;"—and that " nine-tenths " of mankind are knaves, and a large proportion " of the remaining one-tenth, fools." From an equally temporary cause alone, let us hope, also proceeded his evil opinion of some of the gentlemen belonging to a certain branch of the legal profession, whom he called " the anthropophagi of

"London;" and of whom he said, that "if all the "counties in England would join in petitioning "Parliament to make it high treason for any of "the tribe to be found in the realm, it would be "the wisest thing they ever did!" * It was certainly unfortunate for the reputation of Bramah, himself a self-taught inventor of great mechanical ingenuity, that he should have been led, by whatever motive, into systematic and grudging opposition,—(which was also, happily, unsuccessful),—to the grand and prolific discoveries of Watt.

In our own day, this *doctrine of Bramah* appears in this country to have had one, and, so far as we know, but one follower. In a work on the steam-engine by a Mr. Thomas Tredgold, printed in 1827, we find the following passage:—"The for-"tunate idea of condensing in a separate vessel, "which in Watt's engine is the only essential part "in saving of fuel beyond what Smeaton had "accomplished, *would undoubtedly in a short time* "*have occurred to some other person*; and mines "must have been drained at a more economical "rate, long before that monopoly ceased." This observation is accompanied by the further reflection, that "monopoly should never be renewed, "except so that any other person may, at a fair and "at a fixed rate of licence, join in it." Without too critically enquiring how far that can be called a *monopoly, in which any other person may join,*—whether, had Watt not lived, the celestial afflatus

* To Mr. Boulton, 12 April, 1780.

of invention "would undoubtedly" have descended upon, *e.g.*, Mr. Thomas Tredgold, or "some other "person,"—or whether, if the objection is intelligible at all, it does not apply to all grants of patents, quite as much as to any renewals of them,—we need merely remark that in the case of Boulton and Watt's extension of patent, "any other "person" *was* allowed to exercise the invention at a fair rate of licence; which was usually, with great moderation, fixed at only one-third of the savings of fuel which the improved engine in each case effected. The only exceptions to that rule were in cases where the engine worked less than twelve hours a day, or where coals were cheaper than four shillings a ton.

The verdict of the jury, on occasion of both of the trials, having gone with the stream of testimony which flowed so overwhelmingly in favour of the patentees, the judgment of the Court finally established the legal validity of the letters patent, and effectually vindicated the justice of all the claims that Boulton and Watt had made. That decision has always been viewed as one of great importance to the law of patents in this kingdom, and was, of course, productive of momentous consequences in a pecuniary point of view to the patentees; as, besides heavy damages and costs being recovered from the actual defendants, the remainder of the horde of delinquents were thereby, at last, awed into subjection, and compelled to disgorge a large portion of their illegal gains. In judgment on the vanquished, however, mercy was

not forgotten by the victors; and the terms of settlement insisted on were, it is believed, generally satisfactory to all parties. Mr. Watt used, long afterwards, to call the specifications his old *and well-tried* friends.

CHAPTER XII.

TERMINATION OF THE PATENT-PRIVILEGE OF 1769 AND 1775 — AND OF THE ORIGINAL PARTNERSHIP OF BOULTON AND WATT — CONTINUANCE AND INCREASE OF THEIR STEAM-ENGINE BUSINESS — ASSISTANTS AT SOHO — WILLIAM MURDOCK, HIS LIFE, SERVICES, AND INVENTIONS — MR. WATT IN HIS OLD AGE — PNEUMATIC MEDICINES — FOUNDATION OF PRIZE IN GLASGOW COLLEGE — LIBRARY AT GREENOCK — CHARITABLE ACTS.

WITH the year 1800 came the expiration of the privilege of the patent of 1769, as extended by the statute of 1775; and also the dissolution of the original copartnership of Messrs. Boulton and Watt, of five-and-twenty years' duration; a term which had been fixed with a prospective reference to the duration of the privilege, and which, having at its commencement found the partners active and strong,

"In mezzo del cammin' di nostra vita,"

left them, at its close, far advanced on that toilsome journey, and disposed to resign the cares and fatigues of business to other and younger hands. Those two friendly associates, who might well be termed the fathers of the modern steam-engine, did not, therefore, in their own persons renew the

contract which they had in earlier and more eventful times so strenuously, so successfully, and so happily fulfilled. But their respective shares in the concern were readily adopted, as the basis of a new contract, by their sons, Messrs. James Watt, jun., Matthew Robinson Boulton, and Gregory Watt; all distinguished by great talents, and already to a considerable extent initiated in the conduct of the business, by those valuable instructions which the experience of their fathers had so well enabled them to give.

The new partners then entered on a course of enterprising management, from which one of their number, Gregory Watt,* was too soon removed by his premature and lamented death in 1804; but which, in the case of the other two, endured without any material alteration for a period of no fewer than forty years. And it is a remarkable fact, demonstrative alike of the continual advance in the development of the various resources of this country, and of the energetic ability with which the affairs of the Soho manufactory were conducted, that notwithstanding the cessation of the exclusive privilege, and the immense competition in the construction of steam-engines

* This lamented person, having never felt much interest in the dry details of business, was therefore, by the kindness of his elder brother, James, in great measure relieved from them, and enabled to devote his mind solely to those higher pursuits of science and literature in which he found delight; retaining at the same time the independent circumstances and command of leisure which his share of the profits from the steam-engine manufactory enabled him to enjoy.

which speedily followed, so far was the business of Boulton and Watt from diminishing, that it continually increased, and became greatly more profitable than it ever had been in the days of its original founders. During that earlier time, indeed, it never could have been with justice termed highly lucrative; although towards the close of last century, and on the favourable end of the long litigation, it became sufficiently so to satisfy the moderate desires of Mr. Watt, and to remove the fears which had often previously pressed heavily upon his mind, that he might possibly outlive its success.

We need scarcely observe, that during the last half-century the Soho works have been one of the principal sources,—(for a great portion of the time, indeed, *the* principal source),—of that vast supply of steam-power which the inventions of Watt have enabled this and other countries to obtain. At the public meeting in London on the 18th of June, 1824, at which a monument to Mr. Watt in Westminster Abbey was voted, the amount of power which had been thus created at Soho was stated by the late Mr. Boulton to be, in round numbers, equivalent to that of one hundred thousand horses; and since that time, an addition of nearly two-thirds of that amount has been made; giving, up to the present day, a total sum of power equivalent to that of about one hundred and seventy thousand horses. We subjoin a return of the particulars, prepared from the most authentic

records;* and as upwards of seven hundred men are now in full employment at the great establish-

* "MEMORANDUM.—SOHO FOUNDRY, 16 *March*, 1854.

"The number and power of the engines made by Messrs. Boulton, Watt, and Co., to the date January, 1824, were thus reckoned by the late Mr. Boulton and Mr. Creighton (one of his assistants at Soho):—

	Engines,	Nominal horse-power.	Power of living horses required to do the same work.
"283	for pumping and blowing	11,247 × 4 =	44,988
"805	rotative	12,618 × 3 =	37,854
"76	boat engines	2,080 × 3 =	6,240
"1,164		25,945	89,082

"And between January, 1824, and January, 1854, the numbers are the following:—

"34	for pumping and blowing	2,403 × 4 =	9,612
"164	rotative	7,517 × 3 =	22,551
"243	boat engines	15,358 × 3 =	46,074
"441		25,278	78,237

"Giving the following total numbers:—

"1,164	25,945	89,082
"441	25,278	78,237
"1,605	51,223	167,319

"The first engine seems to have been made for Bedworth in 1776."

For the information of those of our readers who are not familiar with the reason of the difference between the nominal horse-power, and what may be called the real or effective horse-power of an engine, it may be mentioned, that an engine of a given number of nominal horses' power can, during a certain time, as *e.g.* from one to six hours, do the same amount of work as could be done by a like number of horses in the same time. But it can do more than this; for a living horse can, on an average, work effectively, day after day, only for about six hours out of the twenty-four, whereas the steam-engine can work for all the twenty-four hours. In order, therefore, to ascertain the number of living horses, and therefore the *real* horse-power that would be required to do the same amount of work that is done by an engine of a given

ment to which we refer, there seems no reason to apprehend any diminution in the future extent of its usefulness and prosperity.

The continued success of the Soho steam-engine works, and the high character of all their manufactures, were unquestionably owing not only to the commanding talents of those who presided over them, but also to the abilities of various excellent assistants; such as were Southern, the two Creightons, P. Ewart, and Lawson, all of whom, in various responsible capacities, rendered energetic and valuable service.* But the foremost place in that honourable rank we must assign to

number of *nominal* horses'-power, the nominal horse-power must be multiplied by four.

This, accordingly, is done in calculations of the effective power of pumping and blowing engines, where the application of the steam-power is *direct*. But in rotative engines, whether on land or for boats, there is estimated to be a loss of power in the action by the crank, &c., as compared with the direct application in the other case, which is allowed for by multiplying the nominal power only by three.

For the same reason, doubtless, it is that the horse-power in pumping and blowing-engines has always been calculated with an effective pressure of 9¼ lbs. on each square inch of the piston, while in rotative engines it is only taken at a reduced effective pressure of 7 lbs.; these numbers being to each other in the same proportion as four to three, or 3 : 4 : : 7 : 9⅓. We are informed, on excellent authority, that "this "mode of calculation is that which was adopted by *the original Watt*, "and is still followed at the Soho works."

* We cannot say less—but, fortunately, their presence among us forbids us to say more—of Messrs. Gilbert Hamilton and James Brown, to each of whom, in acknowledgment of their great and long-tried skill in conducting that extensive business, the late Mr. Watt, of Aston Hall, bequeathed a considerable share in the capital stock of the present copartnership of James Watt and Co. He no doubt felt satisfied that he could not take a more effectual method of insuring prosperity to the great manufacturing association, the interests of which he had so much at heart.

William Murdock, for upwards of half a century Mr. Watt's most able, faithful, and esteemed assistant; who, both in his intellectual endowments, and in the manly independence of his mind, possessed no inconsiderable resemblance to his revered master and friend.

Born in 1754, at Bellow Mill near Old Cumnock in Ayrshire, Mr. Murdock early manifested the most decided predilection for mechanical pursuits; and after qualifying himself for their prosecution chiefly by his own unaided industry, he offered himself to Messrs. Boulton and Watt in 1776, or 1777, and was at once employed by them at Soho in superintending the construction and erection of their engines. He was soon sent into Cornwall as the agent of the firm, where, after vigorously contending with many difficulties, he ultimately succeeded in giving great satisfaction to the mining interest, as well as to his own masters; and he was afterwards employed for nearly twenty years at Soho foundry.

M. Charles Dupin, in an interesting account which he has published* of the great meeting in 1824, for the purpose of erecting a monument to Watt in Westminster Abbey, and his presence at which he says he will ever esteem as one of the most impressive and delightful recollections of his travels in Great Britain, says :—"There was to "be remarked among the spectators a venerable "old man, whose intrepid services I could have

* "Discours et Leçons sur l'Industrie, le Commerce, la Marine, et 'sur les Sciences appliquées aux Arts," tom. i. p. 202, 1825.

"wished had also been rewarded by some flatter-
"ing remarks of public gratitude. Mr. Murdock
"directed the application of the new steam-
"engines, to drain the water of the Cornish
"mines. In order to adapt that moving power
"to exhausting-pumps, and to establish the system
"in mines of extreme depth, inundated by ap-
"palling quantities of water, great skill in prac-
"tical mechanics was requisite. Mr. Murdock
"showed that he was full of all the resources of
"genius, and the wisdom of experience, so as to
"triumph over every difficulty. Scarcely had
"those obstacles been surmounted, than the pro-
"prietors of the mines sought to deprive Messrs.
"Watt and Boulton of the benefit of the agree-
"ment into which they had mutually entered.
"But the incorruptible Murdock showed himself
"insensible to every temptation; he long with-
"stood all menaces, and retired only when he
"saw the cupidity of the men whose frauds he
"defeated, threatening to destroy him in the
"mines by throwing him down their pits." Of this last anecdote of M. Dupin we have heard, from the late Mr. Watt, another version which is somewhat different, and, for many reasons, more likely to be correct;—viz., that some of the "captains" of the Cornish mines, on occasion of a meeting of several of their number with Murdock on business connected with the engines, having attempted to *bully* him, he quietly locked the door of the room in which they were assembled, stripped, and, making a dexterous use

of those arms with which Nature had supplied him, administered to more than one of their number a lesson of persuasive efficacy, such as they would never forget, and such as he was never called on to repeat. He was, in truth, of Herculean proportions, and in muscular power nearly unrivalled.

M. Dupin adds, that he could have wished to have seen Watt, who was so pre-eminent in the art of discovering and attracting to himself men endowed with rare talent, recompensing the skill, the energy, and the integrity of Mr. Murdock, by assuming him as a partner along with Mr. Boulton, in their grand and rich enterprise. But here also we have it in our power to dispel the anxiety which M. Dupin thus again,—perhaps somewhat needlessly,—felt it incumbent on him to manifest on behalf of Mr. Murdock. For although never formally assumed as a partner in the Soho concern, and, therefore, remaining always exempt from all chance of loss in case of that business at any time failing of success, he always received a liberal income from his employers; and from 1810 to 1830, he was placed *on the footing of a partner*, without having to advance a shilling of capital to the partnership funds, without the risk of incurring any liability, and with a fixed salary of 1000*l.* per annum, assigned to him in lieu of a share of the fluctuating profits. From 1830, he lived in peaceful retirement in the neighbourhood of those works to which his energies had been successfully devoted, until his death, which occurred in 1839.

His remains are deposited in Handsworth church, near those of Mr. Boulton and Mr. Watt; where "a bust by Chantrey serves to perpetuate the "remembrance of his manly and intelligent "features," and of the mind of which they were a pleasing index.*

On the subject of the economical employment of gas-light from coal, his systematic experiments commenced in 1792; and for his paper on that subject presented to the Royal Society in 1808, read by Sir Joseph Banks, and printed in the Philosophical Transactions for that year (pp. 124—132), he received the large Rumford gold medal. But that is by no means the only useful discovery with which his name is associated. He secured by patent in 1799 "certain new methods "of constructing steam-engines;" and, in 1810, "an improved method for boring pipes, cylinders, "and circular disks, out of solid blocks and slabs "of stone of any kind or description." In 1809 he made known, without securing it by a patent, a new method of refining porter, &c., without the aid of isinglass, then, as now, a most expensive material; and for this he received a substantial and handsome reward from the brewers of the metropolis. The working-model of the steam-carriage of 1784 (see vol. iii., plate xxix.), shows how aptly he carried out the designs contained in the specifications of Mr. Watt; and the oscillating-cylinder, also engraved for this work (see

* There is also a fine portrait of Mr. Murdock in the hall of the Royal Society of Edinburgh, of which he was a Fellow.

vol. iii., plate xxxiv.), is only one of very numerous and valuable suggestions with which he enriched the wide range of Soho machinery.

Although the commencement of the new æra in the history of Soho found Mr. Watt already past what is commonly called the grand climacteric of man's life, he happily long lived to witness the continued stability and immense progressive increase of his business, in the hands of those dear to himself. His health had never, from his childhood, been robust; and it still was variable; but it had strengthened as his age advanced, and had never, perhaps, been worse than what one of his engineering friends called "a sort of counterpoise "to prosperity, success, or happiness,—or, to "speak more in our own way, a kind of fly-"wheels to the machinery;" * the fatigue of those very exertions which his laborious life had rendered compulsory seeming to have fortified rather than to have enfeebled his frame. His spirits also became naturally more equable, as the principal causes of his anxiety and occasional depression were removed; and while he was destined to be one of those "So strong that they "come to fourscore years," his strength even then, as it could scarcely be termed "labour," was certainly very far from "sorrow." The period, indeed, which commenced with the new century and brought him a release from active business, was a serene and golden time; in which, peace-

* Mr. Telford to Mr. Watt, 17 December, 1801.

fully reposing from the honourable toil of his earlier days, he found a calm and constant satisfaction in their retrospect; and those hours of happy leisure were no less delightful to himself than instructive to the "troops of friends" who, in common with all that can add dignity or cheerfulness to old age, were gathered around him.

A wide range of subjects of a scientific and useful nature continued to attract the notice of his inquiring mind. Among other pursuits, he had been induced, by the sorrow he experienced in losing his daughter, who died of consumption at an early age, "to step," as he expressed it, "over "the bounds of his profession," and to communicate to Dr. Beddoes the ideas he entertained on the employment of "pneumatic medicines." It appeared to him that if poisons could be carried into the system of the lungs, remedies might be thrown in by the same channel; and that, although there seemed to be objections to the introduction, in that way, of powders, such as of Peruvian bark, &c., however finely they might be *mechanically* divided, yet that if the virtues of such substances could be obtained by solution or suspension in air of some species, they might have their full effect when inhaled. With the view of aiding medical practitioners, as well as private patients, in their experiments and researches on this subject, he contrived a convenient apparatus for the preparation and inhalation of the various airs, which was extensively manufactured for sale at Soho. He also in many ways greatly aided Dr. Beddoes in

his establishment of the Pneumatic Institution at Clifton, near Bristol: an establishment famous for having early profited by the services, and developed the chemical talents, of Humphry Davy. The system from which Beddoes hoped so much, although it has never yet realised his large expectations, seemed at first to produce some remarkable results; and it is impossible to despise the importance of facts, or to overlook the ingenuity of deductions which were contributed by men such as Beddoes, Jenner, Edgeworth, Humphry Davy, and Watt, and which led all of them to expect effects of an extensively sanative and beneficial character.*

It was always a favourite wish of Mr. Watt's heart to promote the attainment by others of that spirit of industrious research and invention by which he had himself been so entirely governed; and in the annexed extracts from his correspondence will be found an account of his foundation, in 1808, of a prize in Glasgow College, as some acknowledgment on his part of "the many favours" that learned body had conferred upon him, and of his sense of the importance of promoting the special study of the sciences of natural philosophy and chemistry.† Some years later, also, (in 1816), he made a donation to the town of Greenock, for the purpose of purchasing scientific books for the use of the mathematical school of

* See the "Considerations on the Use of Factitious Airs, and on "the Manner of obtaining them in large Quantities," &c., by Dr. Beddoes and Mr. Watt, published at Bristol in 1794, 1795, and 1796.

† See vol. ii. No. [361], pp. 306—310, *infra*.

the place, under the care and guardianship of the magistrates and town-council: his intention being "to form the beginning of a scientific library for "the instruction of the youth of Greenock, in the "hope of prompting others to add to it, and of "rendering his townsmen as eminent for their "knowledge as they are for their spirit of enter-"prise." This design, carried out (as he wished) by his townsmen, with the munificent aid of his son, the late Mr. James Watt, has been at last completed, and a large and handsome building, containing the library and a beautiful memorial statue of its founder, is now a principal ornament of that busy and prosperous seaport, which boasts that James Watt was born in her.

Nor, amid such donations, given as aids to the promotion of sound and useful learning, were others wanting on his part, such as true religion prescribes, to console the poor and relieve the suffering. But those his benefactions, which were also secret, being usually accompanied at the time by an injunction not to make known the name of the donor, we shall not here seek farther to disclose; preferring to dwell on the comfortable truth, that "there be some persons that will not receive "a reward for that for which God accounts him-"self a debtor: persons that dare trust God with "their charity, and without a witness."*

* Izaak Walton, "Life of Dr. John Donne," p. 54, ed. Oxford, 1824.

CHAPTER XIII.

STEAM-NAVIGATION — ITS ORIGIN AND PROGRESS — PADDLE-WHEELS — EARLY STEAM-BOATS — PAPIN, HULLS, MILLER, SYMINGTON, FULTON, HENRY BELL, ETC.— MR. JAMES WATT, JUN. — HIS VOYAGE IN THE CALEDONIA, IN 1817, TO GERMANY, BELGIUM, AND HOLLAND — H.M.S. THE "JAMES WATT" — LOCOMOTIVE STEAM-CARRIAGES — MR. WATT'S PATENT, AND MR. MURDOCK'S MODEL, OF 1784 — MR. WATT'S VIEWS OF LOCOMOTION ON LAND BY STEAM — EDGEWORTH'S SUGGESTION OF A RAILROAD.

A SUBJECT which naturally excited a deep, and, indeed, at one time, rather an anxious interest in the breast of the great engineer, when resting in his latter days from the severer labours of his life,—

"A guisa di leon quando si posa,"

was that of steam-navigation. With every confidence in the probable success of such a system, he seems never in any very especial manner to have directed the force of his own mind to the details requisite for carrying it out: a circumstance which is quite explained by the constant demands on his time and attention made by other branches of the steam-engine business, so long as he continued to be actively engaged in its prosecution. But in times widely different from those in which

he had asked his memorable question as to whether "a spiral oar" or "two wheels" were to be preferred for navigation by steam, he lived to know of the first complete and practically useful steamboat being successfully employed in America, as well as of the British Channel being crossed, and the Rhine navigated by another; both vessels,—the American and the British,—having been impelled by engines manufactured at Soho, constructed on the principles invented by himself, and not without the benefit of his own direct inspection and counsels.

We have no intention of here entering at any considerable length on the history of steam-navigation,—a subject which has already been treated of by various competent authorities, and which perhaps offers materials for a still more comprehensive work than any that have yet appeared. But it may generally be remarked, that the introduction of that most valuable mode of conveyance and transport has been quite dependent upon, and nearly co-ordinate with, Mr. Watt's improvements on the steam-engine; that before those improvements were made known to the world, nothing of any importance in that way had been accomplished, and little even attempted or imagined; and that since the full development of those improvements, that perfection of power and safety with which the ocean is now traversed in every direction and to any distance, by vessels impelled by steam, has been rapidly and triumphantly

attained. To this end the ingenious industry of many successive engineers and mechanics has, it is true, eventually conduced: but the master-key which unlocked the *power* required for the performance of such a task, was the condensation of steam in a vessel separate from the cylinder, together with the means of converting the rectilineal motion of the piston-rod into a rotative one for paddle-wheels, or, as now practised, for a screw-propeller, or "spiral oar."

The mere use of paddle-wheels, "remi rotatiles," or "rames tournantes," moved by animal force, for the progression of boats, appears to have been of considerable antiquity. Not to carry our inquiries further back, they have been fully described by Valturius, in his great work on the Science of War, in 1472; by William Bourne, in 1578; by Denis Papin (as having been seen by him in use in England, probably in 1682), in 1690; by Savery, in 1698; by Du Quet, in 1702 and 1735; by the Comte de Saxe, in 1732, &c. Papin, also, in 1690, unquestionably suggested the employment

* The steam-vessels of modern times may well remind us of the

"Wondrous ships self-mov'd, instinct with mind,"
Pope's Homer's Odyssey, b. viii. l. 604.

of Alcinous and his Phæacians. Nor is the

"——— λαῖτμα τάχιστ' ἀλὸς ἐκπερόωσιν,
"Ἠέρι καὶ νεφέλῃ κεκαλυμμέναι"—

of the original, less forcibly descriptive. We wish we could with equal verisimilitude continue the quotation:—

"——— οὐδέ ποτέ σφιν
"Οὔτε τι πημανθῆναι ἔπι δέος, οὐδ' ἀπολέσθαι!"
ΟΔΥΣΣ. Θ. 537-9.

of *the atmosphere* as a power, with a vacuum formed by the condensation of steam beneath a piston in a cylinder, the power being communicated by toothed and paddle-wheels "ad naves adverso "vento provehendas:" representing the greatest probable obstacle to the construction of such a machine to be the difficulty of getting cylinders of adequate size sufficiently well made for the purpose they were intended to serve. Of the mere ingenuity of his suggestion, so far as it went, there cannot, of course, be a doubt; but this, like some others of his mechanical ideas, he seems not to have seriously attempted to reduce to practice. If he had done so, he would have found how entirely insufficient was the apparatus he proposed, now dignified by some writers with the name of his steam-engine, to produce such effects as he desired. For the water was placed in the cylinder, the fire lighted beneath it, and, after each rise of the piston, the fire was again removed, so as to allow a gradual condensation, and a tardy as well as feeble stroke; so that, although the principle of forming a vacuum by the condensation of steam was certainly novel and curious, and might have led to greater results, as it afterwards did when differently modified and used by Savery and Newcomen, it seems impossible to assign to Papin the merit of having himself thereby attained any really important practical results.* The mechanical difficulty, also, which he has speci-

* See vol. ii. p. 233, note, *infra*.

fied, although unquestionably very considerable, was only one of many which Mr. Watt's more comprehensive view foresaw, and which it needed all the most constant and anxious exertions of his more powerful practical genius to encounter and overcome. Since the days of Papin, indeed, the experience of a century and half has fully enabled us to judge how great was the distance between the imperfect conception of a project, such as he suggested in the passage quoted above, and its successful consummation.

It still, curiously enough, remains uncertain whether Jonathan Hulls carried into effect the more elaborate invention for which he obtained a patent in 1736, and which he set forth in his celebrated pamphlet entitled 'A Description and 'Draught of a new-invented Machine for carrying 'Vessels or Ships out of or into any Harbour, 'Port, or River, against Wind and Tide, or in a 'Calm:' London, 1737. But he has at least minutely described the introduction of a Newcomen's engine into a large boat or barge to be employed as a tug, and has delineated such a vessel, fitted with fan (or paddle) wheels, towing a ship of war of upwards of thirty guns. His work, which seems to have been long overlooked, is now not common, and it is still more rare to meet with a copy containing the curious and highly illustrative engraving which forms its frontispiece; but it affords the strongest evidence which we possess of a marine atmospheric steam-engine, working by paddle-wheels, having been

constructed, or, at all events, fully devised and figured in action, so early as the period in question.

After the date of Mr. Watt's patent of 1769, (the great pivot on which all real advancement in the steam-machinery of modern times has turned), it is said that, in the United States, Mr. Ellicot, in 1775, and T. Paine (less favourably known by his writings), in 1778, suggested the use of steam for propelling boats; as the Abbé Arnal did in France in 1781, for inland navigation; while in 1782 the Marquis Jouffroy built a steam-boat, which was tried on the Saône, but did not succeed. In 1783, Mr. James Rumsey of Virginia and Mr. John Fitch of Philadelphia both proposed methods of propelling boats, the one by a current of water forced out at the stern, and the other by paddles, but not in the form of wheels. It is said that Mr. Fitch constructed a steam-boat which was navigated between Bordentown and Philadelphia, but was soon laid aside.

In 1787, Mr. Miller of Dalswinton published a description, with engravings, of a triple vessel, propelled by paddle-wheels, turned by means of cranks, intended to be worked by men; adding, "I have also reason to believe that the power of "the steam-engine may be applied to work the "wheels, so as to give them a quicker motion, "and, consequently, to increase that of the ship." In 1788, Mr. Miller employed Mr. William Symington, of Wanlockhead, in Dumfries-shire, along with Mr. James Taylor, to superintend the

construction of a small steam-engine in a pleasure-boat on Dalswinton Loch. This succeeding well, induced him to employ Mr. Symington to construct a larger steam-engine at Carron, for one of Mr. Miller's boats on the Forth and Clyde Canal, which was tried in 1789, and a speed of about seven miles an hour attained; but from other objections, (chiefly to the want of solidity in the machinery), from Mr. Miller's want of confidence in its ultimate success, and his attention being diverted to other pursuits, the boat was soon afterwards dismantled, and the engine removed from it. It has been lately stated that about the year 1787 Messrs. Furnau and Ashton made experiments in steam-navigation on the river at Hull, which ended in their building a boat which for some time plied between Beverley and Hull, and another of a larger size, which was bought by the Prince of Wales, afterwards George IV., and fitted up as a pleasure yacht. The latter vessel is said to have been burned: what became of the former is not stated.

From January, 1801, to April, 1803, Mr. Symington was employed by Lord Dundas to make a series of experiments on steam-boats, with the view of their being used on the Forth and Clyde Canal; and the towing-vessel, the "Char-" lotte Dundas," which he then constructed, appears to have been entirely successful, in so far as regarded moderate power and speed. The use of this vessel, however, on the canal was discontinued in consequence of the injury which it was

apprehended the washing of the waves in its wake might do to the banks; and although the Duke of Bridgewater was so satisfied of the advantages of the invention as to have given Mr. Symington an order to build eight similar boats, to be used on his canal, yet the hopes of the enterprising inventor were destined to be crushed just at the very "moment of projection;" for "the same day "that he was informed by Lord Dundas of the "final determination of the Committee not to "allow steam-boats to be employed on the canal, "he received intelligence of the death of the "Duke of Bridgewater." *

In 1801, Symington's steam-boat was visited, minutely inspected, and tried by Robert Fulton, a native of Pennsylvania, (the son of an emigrant from Dumfries-shire), who, as an engineer—not merely an amateur—devoted much time and attention to the subject of steam-navigation. And early in 1802, he being then resident in Paris, and in full communication with Mr. Livingstone, the envoy from the United States to France, who appears to have been attached to similar pursuits, he addressed a letter to Mr. James Watt, jun., in which he inquired the price and other particulars of a small engine of five horses power. In a letter written a week later, he made inquiries as to the employment of high degrees of heat in small engines, and the limit to which it might be carried, in order to render them light and com-

* Woodcroft 'On Steam-Navigation,' 1848, p. 55.

pact,—for this, with his views, was necessarily a cardinal point,—and then he went on to say, "The "object of my investigation is to find whether it "is possible to apply the engine to working boats "up our long rivers in America. The persons "who have made such attempts have commenced "by what they called improving Watt's engine, "but without having an idea of the physics "which lay hid in it from common observers; but "such improvements have appeared to me like "the improvements of the preceptor of Alcibiades, "who corrected Homer for the use of his scholars. "Their ill success, and their never having found "a good mode of taking a purchase on the water, "are the reasons why they have all failed. "Having, during the course of my experiments "on submersive navigation, found an excellent "mode of taking a purchase on the water, I wish "to apply the engine to the movement. The "only thing which is wanting is to arrange the "engine as light and compact as possible," &c. And in the postscript of his letter he proposes for Mr. Watt's consideration some schemes of engines suggested by Mr. Livingstone: schemes on which we do not find that any opinion was then expressed, but which appear not to have been very clearly explained, and, in so far as their construction was intelligible, did not promise to be very effective.

On the 6th of August, 1803, Mr. Fulton ordered his first engine from Soho, repeating the application in person in 1804. The diameter of

the cylinder was 24 inches, with a stroke of four feet, being about nineteen horses power. "The "principal parts of the engine were made and for- "warded early in 1805; the planning and execu- "tion of the subordinate parts, as well as of the "connecting and paddle machinery, having been "undertaken by Mr. Fulton himself. He built a "vessel from his designs at New York, called the "Clermont,* and having erected the machinery "on board of her, the first trial was made in the "spring of 1807, and was eminently successful; "and this vessel was soon after established as a "regular steam-packet between New York and "Albany." †

Within six years from the first trial-trip of the "Clermont," six steam-vessels had been built for Mr. Fulton, and were in constant and successful use in America for the conveyance of passengers.

In 1811, Mr. Henry Bell, a citizen of Glasgow, who, since 1800, had repeatedly urged the subject of steam-propulsion on the attention of the British government, and had also aided Fulton with drawings of machinery, &c., took the decided and enterprising step of himself trying in Scotland, at his own risk and under his sole direction, an experiment similar to that which had succeeded so well in America. He had a boat, called from the great heavenly body of that kind which made its

* From a residence of Mr. Livingstone's on the Hudson river, about two-thirds of the way from New York to Albany.

† The distance between New York and Albany has, we believe, been ascertained by a recent survey to be 125 geographical miles.

appearance in that year, the "Comet," built at Port Glasgow, in the yard of Messrs. J. and C. Wood, which, propelled by a steam-engine of his own construction, was finished by the end of 1811. It plied on the Clyde, between Glasgow and Greenock, early in 1812; and thus became the forerunner of that system of practical steam-navigation which has since so widely extended itself in this country. The "Comet" was forty feet in length, of twenty-five tons measurement, and four horses power; but other vessels soon followed of somewhat greater dimensions, fitted with engines of proportionally greater powers;—the largest, built in 1813, of which we are aware, being the "Glasgow," of 74 tons and 16 horses power,—in 1814 the "Morning "Star," of 100 tons and 26 horses,—and in 1815, the "Caledonia," of 102 tons and 32 horses. In that year two steam-vessels went from the Clyde to the Thames; one by the Forth and Clyde Canal to Leith, and thence by the east coast; and the other by the west coast and round the Land's End:—these being, so far as we know, the first attempts at steam-navigation made in the open sea of our coasts.

In April, 1817, Mr. James Watt, jun., having purchased the "Caledonia," which from defects in her engines had been little used since her launch in 1815, had her machinery taken out, and replaced by two new engines of Soho manufacture, of 14 horses power each. In October of that year he went over in her to Holland, and ascended the Rhine as far as Coblentz; having thus been the

first to leave the British shores and cross the Channel by so novel, and, as it was then esteemed, so hazardous a mode of transit. But although

"Illi robur et æs triplex
"Circa pectus erat,"

even he could scarcely then foresee that in later days the imitation of his daring enterprise would be circumscribed only by those bounds by which the proud waves of the ocean are stayed.

The "Caledonia" having left Margate on the 14th of October, 1817, arrived off West Kapelle, Walcheren, in ten minutes more than twenty-four hours, and came to anchor in the Keeting near Vianen three hours later; having run under steam, at an average speed of 7½ knots an hour. In her voyage from Rotterdam to Cologne, by Nimeguen, Emmerick, Wesel, and Dusseldorf, the time actually occupied under way, with a strong easterly wind and current against the vessel during the whole of it, and for nine hours only one engine at work, was 48 hours, 52 minutes. As she steadily forced her way against the impetuous waters of the Rhine, and her track was marked by—

"Smoke in air and foam upon the wave," *

she excited, as may well be imagined, the admiring wonder,—in some cases the wondering horror,—of the natives. She presented a strange contrast, such as has often since struck the eye of the

* Cary's Dante, Hell, canto xxiv. l. 50.

traveller, to those most shapeless and primitive of all vessels, the huge rafts of timber from the Helvetian forest, which with whole families, with their flocks and herds, inhabiting them for weeks together, seem, as sluggishly they descend the stream, to be leviathan villages of diluvian date.

On her homeward voyage from Coblentz, the "Caledonia" entered the Scheldt, and visited Antwerp. She was then laid up for part of the winter in the harbour of Rotterdam, for repairs and alterations. After her return to the Thames in the spring of 1818, Mr. J. Watt, jun., made no fewer than thirty-one series of experiments with her on the river (the whole number of those experiments amounting to two hundred and fifty); * which resulted in the adoption of many most material improvements in the construction and adaptation of marine engines, and in an immense, though gradual extension of that branch of the manufacture at Soho. From the particulars already given † of the amount of steam-power produced at that establishment, it appears that the marine engines manufactured there up to the present year (1854) were in number 319, of 17,438 *nomihal*, or 52,314 *real* horse power.

The memory of James Watt will now be

* From a memorandum made by one of the party present on the occasion, we find that on the 14th of July in that summer, the "Caledonia" steamed to the Nore and back—nearly 100 miles—in ten hours; to the great astonishment, among others, of a French gentleman on board, and the delight of Chantrey the sculptor, who was another member of that party of pleasure.

† See p. ccxii. *supra*, note.

worthily perpetuated in the British navy, by the fine screw steam man-of-war of that name, of 90 guns, which was launched at Pembroke dock-yard in 1853, and fitted with Soho engines.* And as we write, we are informed that engines are now preparing at the same great manufactory for a vessel which is to be 700 feet in length, of the enormous capacity of 22,000 tons, and to be propelled by no less a power than that of from 2000 to 3000 horses!

With regard to another application of steam power, of kindred interest and importance, that, viz., to locomotion on land, it is remarkable enough that when Mr. Watt's attention was first directed, by his friend Robison, to the steam-engine, "he (R.) at that time threw out an idea "of applying the power to the moving of wheel-"carriages." "But the scheme," adds Mr. Watt, "was not matured, and was soon abandoned on "his going abroad." † In the seventh "new "improvement," however, set forth in the specification of his patent of 1784, Mr. Watt described the principles and construction of "steam-engines "which are applied to give motion to wheel-

* The engines in question, as we have been informed by one of their makers, were originally intended for the "Vulcan," to exert the power of 700 horses at 60 strokes per minute; in the "James Watt," owing to the employment of a larger size of screw-propeller, they are only to make 50 strokes per minute, and the estimate of their power will be reduced to that of 600 horses. In casting the fine brass screw-propeller for H.M.S. the "James Watt," *ten tons and a half* of metal were employed.

† Robison, p. 113, and p. lxvii. *supra.*

"carriages for removing persons or goods, or "other matters, from place to place." They were to be worked by high-pressure steam, "at "least one and a half times as dense as the "common steam," which he also calls "violent "steam;" * and in one of the alternative forms of engine, for that purpose, which he specifies, he says that after the steam has performed its office, (of giving motion to the pistons, and causing them to make their stroke), he discharges it into the atmosphere, by a proper regulating valve. We have elsewhere † mentioned that, also in 1784, Mr. Murdock made a working model of a locomotive engine upon that principle, which performed well, and is still in existence. With a spirit-lamp for a furnace, its cylinder attached to the boiler, and its piston-rod working a beam that turned the driving wheels by a crank, it was placed in the Great Exhibition of 1851,‡ where it attracted much notice. It stood among the "machinery at "rest," on the colossal marine engines, of 700 horse-power, manufactured by Messrs. James Watt and Co., which have since been erected in the fine 90 gun screw steam-ship the "James Watt;" and by the side of that interesting little model was placed another, also of diminutive size, of a steam-engine with *an oscillating cylinder*, invented and constructed by Mr. Murdock in the year 1785. The model of the locomotive engine is now in the

* Vol. ii. p. 197, *infra*; see also p. ccxvii. *supra*.

† Translation of Arago's "Eloge of Watt," p. 120, *note*, ed. 1839.

‡ See the "Official Catalogue," vol. i. p. 211.

possession of Messrs. James Watt and Co.; that of the oscillating cylinder remains, a valued heir-loom, in the family of Mr. Murdock; and both of these curiosities of the engineering art have been, by the permission of their respective proprietors, delineated and engraved for this work.*

Without, then, trespassing on the undoubted rights of a Stephenson, to whom belongs the glory of establishing the magnificent system of railway travelling so characteristic of our days, or on those of others, who have mainly assisted in its development, Mr. Watt may, to a certain extent, be looked upon as the first inventor of practical means for effecting locomotion on land by steam. A full record of his examination of the matter so far as it went, and a discussion of its probable relative advantages and disadvantages, will be found in one of his letters to Mr. Boulton in 1784,† the year in which he obtained the patent we have just referred to. But it is also undeniable, that his expectations of a profitable result from the employment of such a machine as he had there specified, were at all events very uncertain; that he considered the question as being confined to the movement of carriages upon roads such as were usually employed for traffic throughout the country; and that, although "on a hard smooth "plain," where there would be little friction, he seems to have thought it might be practicable enough, yet that, on the whole, under the pressure

* See vol. iii. plates xxix. and xxxiv. † Vol. ii. p. 194-201, *infra*.

of the full employment which the rest of his business then daily forced upon him, he both himself declined the prosecution of that newly-imagined branch, and strongly dissuaded Mr. Murdock, who was evidently well disposed to have gone on with it, from doing so.

The experience of more than half a century has since amply demonstrated, that upon the question as so limited in Mr. Watt's contemplation, viz. as it concerned engines to be used upon common roads, his distrust of a successful result was very far indeed from being unfounded. But evidently one great cause—perhaps the principal one—of his comparative disregard of the further prosecution of this great practical experiment, as well as of the not less arduous one of steam-navigation, was the constant and advantageous employment of the Soho works in the construction of stationary land engines, of which the effect was not doubtful, and which required, in order to the perfection of their manufacture, and the consequent completeness of their operation, the best and most undivided attention that their makers were capable of bestowing. It was for no want of discernment of the interesting nature of the problem as he proposed it to himself, nor, as our readers may well suppose, from any deficiency in inventive ingenuity, that he deferred its further solution; for although he seems to have been rather inclined to prefer "a short working-beam" to direct action from the piston-rod, and to consider the proper place for the engine to be *behind* the carriage to

be propelled, and forming a part of it, still the "violent steam," "let out by successive puffs,"—the copper boiler, "cylindrical, with a number of "tubes passing through, like the organ-pipe con-"denser,"—the use of "coke instead of coal," to prevent "the disagreeable circumstances of soot "and smoke," without, however, being able altogether to avoid "the sulphureous air" when going before the wind,—and the shaking of the carriage, "superseding the necessity of poking the fire, but "being apt to waste the cokes, by making them "fall through the grate before they are consumed,"—form a series of particulars which bring before the mind an image not very dissimilar in its principal features from the well-known locomotive engine of the present day.

It appears also, from two of his letters printed in this work,* that in September, 1786, Mr. Watt had a steam-carriage "of some size under hand," and was "resolved to try if God would work a "miracle in favour of these carriages;" although he also had "small hopes of their ever becoming "useful," and "suspected that the age of miracles "was past."† His experiments of that sort appear to have been interrupted by his journey to Paris in the winter of 1786-7, as well as by his finding that "William [Murdock] applied himself "to his business," without further urging the carriage scheme:—and they do not appear to

* To Mr. Boulton, 12th September, and to Dr. Black, 5th October, 1786, vol. ii. pp. 210 and 213, *infra*.

† To Mr. Boulton, 23rd September, 1786, vol. ii. p. 211, *infra*.

have been afterwards resumed. But his friend Mr. Edgeworth, (whether in consequence of any previous communications with Mr. Watt, or solely from his own ingenuity, which was very considerable, we know not), seems to have made a wonderfully near approximation to the real secret which alone was wanting to bring the whole system into activity, when he writes, "*I have always thought* "*that steam would become the universal lord, and that* "*we should in time scorn post-horses. An iron rail-*"*road would be a cheaper thing than a road on the* "*common construction.*"

* To Mr. Watt, 7th August, 1813. See vol. ii. No. [387], *infra*.

CHAPTER XIV.

ARITHMETICAL MACHINE — MACHINE FOR COPYING SCULPTURE — ITS GRADUAL PROGRESS, AND ITS PERFORMANCES — DATES, AND EXTRACTS FROM MSS. CONCERNING IT — INTENDED SPECIFICATION OF A PATENT FOR ITS INVENTION — RELATIVE DRAWINGS — ACCOUNT OF THE TIME EMPLOYED IN ITS OPERATIONS — PERFECTION OF THE WORK DONE — LATER PROCESSES OF A SIMILAR KIND.

THE arithmetical machine, on which Mr. Watt says, in 1785,* that he had been turning "some "of his idle thoughts," he does not appear ever to have prosecuted further than by mentally considering the manner in which he could make it perform the processes of multiplication and division: processes which may be held to imply the earlier steps of addition and subtraction. But in a mind such as his, this may safely be presumed to have been already no inconsiderable stage of advancement towards the completion of such a machine. He calls the arrangement of it, as so provided for in his own view, "exceedingly "simple;" but speaks modestly of "making an "attempt at making it," and of it being only an attempt, from his experience of the difficulties

* Mr. Watt to M. De Luc, Dec. 11th, 1785. No. [276]. Vol. ii., pp. 208–9, *infra*.

which in mechanics intervene "between the cup "and the mouth." Of the wisdom of this caution no one, probably, has been made more fully aware than that ingenious machinist of our own time,* who, at great cost, and with still greater expenditure of ingenious thought and unwearied application, succeeded in producing a machine which realised even more than Mr. Watt's early announcement contemplated.

But one engrossing occupation, nearly akin to those of his earlier, but what we can hardly call his better days, Mr. Watt also found in gradually perfecting a sculpture-machine: a highly ingenious invention, the idea of which was suggested to him by an implement he had seen and admired in Paris in 1802, where it was used for tracing and multiplying the dies of medals. He foresaw the possibility, if only some mechanical difficulties could be overcome, of so enlarging its powers as to admit of it making in wood or the softer kinds of stone,—nay, even in marble,—copies of works of sculpture, which should be perfectly true to their originals, although of a smaller size; and the imagination of such an exploit seems to have been peculiarly delightful to him, combining as it did some elements of more than one of his other favourite inventions. For the new machine was to

* It is scarcely necessary for us to do more than allude to the name of Mr. Babbage; the success of whose difficult pursuits has been so honourable, not only to himself, but also to the mechanical skill of this country, already most highly distinguished in the line of his predilection.

do, for solid masses and in hard materials, what his copying-machine of 1782 had already done for drawings and writings impressed upon flat surfaces of paper; while it was necessary that the movements requisite for such a purpose, however complicated they might unavoidably be, should possess great power to act on the obdurate substances subjected to their operation, and be at the same time as entirely under control as if regulated by the gentle energy of the "governor," and acting with all the delicate smoothness of the "parallel motion."

Of the exact date when he began to construct the first parts of this novelty in the engine department, we have been unable to find any precise note. The first clear indications that we have met with of his making use of anything that approached to the reality of such a machine, occur in 1807 and 1808, when its construction appears to have been considerably advanced, and he got from London some models to copy,—"small busts "of Socrates and Aristotle, and a sleeping boy, "sent by Turnerelli, the sculptor." * He then also ordered some diamond cutting-pencils for what he termed his "Parallel Eidograph." † By April, 1809, he had "made considerable progress "with the carving-machine, and it seemed neces- "sary to christen it with a Greek name," which to Professor Young, then the accomplished Professor of Greek at Glasgow College, he suggested

* 25 July, 1807. † Nov. 1808.

might be Iconopoïa, Iconurga, Iconoglypta, Agalmatopoia, Glyptes, Polyglyptes, Glyptic machine, &c., names to which he afterwards added those of Bust-lathe, Statue-lathe, Pantograph, Double Pantograph, and Double Parallel-lathe. At the same time he got for it, besides gouges and other tools,* "drills made in steel frames of peculiar con- "struction, to turn with great velocity and with- "out a shake;" and before the end of May of that year he wrote to his friend, Dr. P. Wilson, that he had now made the glyptic machine polyglyptic, as he could do two or more copies at once, but that it was "still far short of his ideas: *Ars longa*, "*vita brevis*." At the same date he informed his son James that since getting his new drill-frames from Manchester, (where they had been made by a skilful workman of the name of Green, under the immediate superintendence of the eminent machinist Peter Ewart), he had tried them only so far as to find that he could work two drills at once, and that he had finished "a large head of "Locke in yellow wood, and undercut, and a "small head of Dr. [Adam] Smith, in ivory, "which were both done on the iron platform: "the former not so well," he adds, "as I expect "to do, but very well." Other occupations interfered to prevent his doing other carvings at that time.

Six weeks later† he explains to Professor Young the origin of the machine, which was now

* 30 March, 1809. † 7 July, 1809.

so far advanced, saying, "There is a machine "of the nature of a turning-lathe, which copies "medals and other things in bas-relief; it is "called in France *tour à médailles*, in English the "*likeness-lathe*. I have thought of some improve- "ments on it, which somewhat extend its uses; "(this is at present a secret, which I do not wish "to be spoken of)." Throughout that and the following year he gave various directions to Mr. Murdock, then, as always, his most able assistant at Soho, and to Mr. Peter Ewart at Manchester, who gladly performed for him the like friendly offices, as to the improvement of some of its separate parts, observing to the latter gentleman, "You "know my anxiety to complete it while I can." * To his friends, MM. Levêque and Berthollet also, he described the stage of its progress at which the machine had arrived, and his intention, if he should live to complete it, of communicating a full account of its construction to them.†

Early in 1811 he wrote to Dr. P. Wilson that his invention continued to succeed, and that he had realised some more of his ideas on the subject, having, by very accurate construction of the machine and adjustment of the tools, &c., overcome the difficulty of getting "the several segments "which form the surface of the bust to meet;" and having executed several small busts in alabaster, he "not being strong enough to work "marble."‡ Also, that whereas the specimens Dr.

* 3 May, 1810. † 14 March and 26 Dec. 1810.
‡ 7 March, 1811.

Wilson had seen were done by the cutting-tool and the guide-point moving in parallel lines, which were either straight or circular, and very near each other, he had now contrived, though not executed, that the two "points, the guiding "and the cutting-point, might move in any line, "straight or crooked, square or diagonal, so that "an inscription might be cut in stone from a "drawing on paper. But there is some art," he observes to Mr. P. Ewart, "in making a drill, "while continually varying its situation, turn "round regularly with any desired velocity; and, "on the whole, there is some art required in the "use and application of the tools, which experi-"ence only has taught me." *

During the next three years, notwithstanding the "garret," in which the machine and all its appurtenances were placed, being too hot in the heats of summer,† and too cold in the depth of winter,‡ for the old man to spend much time in the great variations of temperature which he encountered under its roof, the progress he still was making, and the interest he continued to feel in his curiously skilful process, were attested by "very smooth work on an Egyptian head" he was cutting in mahogany,§ as well as by "a little "figure of a boy lying down, and holding one "arm, very successfully done; and another boy, "about six inches high, naked, and holding out "both his hands, his legs also being separate."

* 9 May, 1811. † To Mr. P. Ewart, 11 July, 1811.
‡ To the same, 27 Feb. 1814. § To Mr. Murdock, 7 Dec. 1812.

"But I have been principally employed," he adds, "in making drawings for a complete machine, all "in iron, which has been a very serious job, as "invention goes on very slowly with me now."

Not only did Mr. Murdock soon finish the manufacture of the "new loom, which looks very "scientific and answers its purpose," but Mr. Watt, although still seeing "much to be done," had, by March, 1814, "succeeded tolerably in making "drills for working marble, which has hitherto "been a matter of difficulty;" and in the following autumn he wrote to his engineering friend Mr. John Farey, jun., "my machine is now under-"going one of its ultimate changes, and I expect "very soon to have it completed."

Accordingly, in September of the same year, he wrote what appears to have been intended as the title and commencement of a specification of a patent for the invention. The title shows that the description stops short altogether of one of the two species of machines intended to be included in it; it is also obviously incomplete as to many particular proportions and movements of the several individual parts requisite for producing the desired effect. But of all of them, accurate drawings, beautifully made by himself, to a scale, remain; showing that the machines were not only completed in fact, and used in practice, but were also carefully delineated by him, with a view, no doubt, to the relative drawings proper to be attached to such a specification, when delivered in at the Patent Office. The invention having been

thus fully completed, and having also been publicly used by Mr. Watt in making the frequent copies of various specimens of sculpture which he, from time to time, distributed to his friends, operated, in more than one instance, to prevent patents being subsequently taken out by others for similar ingenious machines.

The following is the fragmentary description to which we allude, and which is dated September 21st, 1814:—

"Certain new methods, machines, tools, and "processes, by means of which copies, duplicates, "or imitations are or may be executed, cut, "carved, or made from the originals, casts, or "models of statues, busts, medallions, seals, dies, "moulds, mouldings, and other carvings, bent, "waving, and uneven surfaces, in or upon some "sorts of metal, ivory, bone, horn, tortoise-shell, "wood, marble, and certain other stones and other "substances; so that the said copies are or shall "be of the same, or of some greater or lesser size "than the said originals, within certain limits as "may be desired.

"The said machines are of two kinds: First, "those which are intended to form copies of lesser "or greater dimensions than the originals or "patterns; and secondly, those which are in-"tended to form copies of the same size as the "originals or patterns.

"I begin with the first kind, as being the most "simple in their construction. They consist of a "bar, beam, or radius, having one universal joint

" or other centre-piece, at one end, which permits " the other end to be moved in any direction, but " will not permit the said bar or beam to turn " upon its own axis in any sensible degree. This " beam is connected by the said joint with one end " of an oblong platform, upon which are guided " two tablets, in such manner that they can be " slid to and from the centre without lateral shake. " Upon the said beam are fixed two sockets, each " carrying a point perpendicular to the surface of " the said tablets; and the distance of these points " from the centre of motion of the beam is pro- " portioned to the difference of size which is in- " tended to be made between the patterns and " the copy, so that when the one point called the " guide, (which must be more or less blunted), is " drawn backwards and forwards upon the pat- " tern, (which is fixed upon one of the tablets), " the other point, which is sharp or cutting, may " cut or form a line upon the block or substance " to be operated upon, which is fixed upon the " other tablet, similar in its elevations and de- " pressions to the line traced by the guide-point."

On one of the drawings Mr. W. has written " This pantograph will serve to reduce to $\frac{1}{2}$, $\frac{1}{4}$, and " $\frac{1}{8}$. A similar one will reduce to $\frac{1}{3}$ and $\frac{1}{6}$; $\frac{1}{5}$ and $\frac{1}{7}$ " are not so useful, and may be omitted."

On the backs of letters there remain some notes made by Mr. Watt, of the time occupied by him on several days in succession in making copies of busts with the diminishing machine: one specimen of such rough journals we give here, as indicating

the various steps of the process and the comparative time occupied in each. The result was a beautiful head, in alabaster, which still exists in the possession of Mr. Watt's representatives; but it was done before the attainment of all the facility with which some later improvements of the machine enabled the operator to work, and which gave greater rapidity of execution :—

Bust of Sappho, January, 1811.

		Hour.
" Jan. 28.	Making pedestal, 1 hour	1
" 29.	Soaking in a strong coat of oil-varnish, and cement- " ing the bust on pedestal	1
" 30.	Cutting out the stone, cementing it and the bust " to the moveable plates, and fixing the centres	3
" 31.	Roughing the stone with the tearing-drills to with- " in the thickness of a halfpenny of the truth .	9
" Feb. 1.	Going over it with the quarter-inch drill to within " the thickness of a thin sixpence.	5
" Saturday 2.	Doing the face with the 1-8th drill to the truth, " from the outer corner of one eye to do. of the " other (went too slow)	5
" 3.	Doing her breast with do.	1
" Monday 4.	Do. one side of the head	4
" Tuesday 5.	Do. round to within 1-4th of the whole . . .	4
" 6.	Quite round, finished the shoulders, removed some " of the steps, or plaits	3
" 7.	Cut the crown of the head, undercut the neck, and " cut it off from the centre-piece, repaired the " most of it	3
		39

If it should be discerned by any rigidly censorious eye, that of the Thirty-nine Articles of which this number of hours consists, one is entered to the account on *a Sunday*, we would remark that to Mr. Watt, at that time, a day which passed without "a touch at" his favourite machine might

perhaps have been felt as no day of real rest:—but that at all events the time occupied in his brief labour did not equal that of the "Sabbath-"day's journey" permitted under the old Judaical dispensation even by those who lived, "after the "most straitest sect, Pharisees." Such philosophical rather than theological employment of the sacred day, however, even if only partial and occasional, will recall to the mind of some of our readers the dying request of Johnson to Reynolds, *that he would not paint on Sundays*; an affecting entreaty, with which, we need scarcely add, that great master very religiously,—and in the end, no doubt, very profitably,—complied.

In 1816, the machine underwent some further improvements, "to assure steadiness in its work-"ing," but in August, 1817, Mr. Watt feeling "very "languid and unfit for exertion of any kind," and also experiencing "an occasional dimness of sight "which rendered it at times difficult for him to "write even with spectacles," deferred his superintendence of further changes which were to be made on it, till his return from his tour in Scotland. Some later notices that we have of it from his hand are interesting ones; for in the end of 1817 we find him writing to his friend Chantrey, then near the summit of his fame as the first of British sculptors, "the diminishing machine is made ready "for the trial;" Chantrey replied in the following March expressing the great desire he felt, from the report Mr. Rennie had made to him, to examine the machine; and offering a visit to

Heathfield for that purpose in June "if you will "be kind enough to encourage me with a promise "that I shall then see it." The desired invitation was duly sent; but when Chantrey next passed through Birmingham, (on his return from Scotland in 1818), it unfortunately happened that Mr. Watt was absent from home, and the great sculptor's curiosity therefore remained unsatisfied. The last drawings which Mr. Watt made of any portions of the machine are dated by him February and April, 1818. But it does not appear that, in the last year of his life, he did much more to or with it. It seems by that time to have been nearly or altogether perfect; and his failing strength probably unfitted him for and disinclined him to much exertion even in such old and loved pursuits. Then—

"Came the blind Fury with th' abhorred shears,
"And slit the thin-spun life. 'BUT NOT THE FAME,'
"Phœbus replied, and touch'd my tingling ears."

The sculpture machine,—the youngest of his mechanical offspring,—the child at once of his old age and of his right hand,*—had always been a great favourite with its venerable progenitor; and it is not difficult to imagine the sort of charm he must have felt in thus "searching for beautiful "forms into the heart of marbles, and bringing "them out into full daylight." The means required in order to such graceful elaboration,—not indeed unattended with difficulties, such as in other

* See Gen., chap. xxxv., v. 18. "His father called him Benjamin;" "*i.e.*" (adds the marginal interpretation) "the son of the right-hand."

undertakings on a more gigantic scale he had been accustomed to meet and to overcome, but free alike from either anxiety or monotony,—gave occasion to many hours of quiet inventive meditation and moderate manual exercise, such as befitted the weight of his years, and did not interfere with the seclusion which he loved. His plastic performances were usually distributed among his intimate friends, with playful apologies for the imperfect skill of *so young an artist*; but some remained in his own possession, and judging from those we have seen, they displayed not only all the breadth and boldness of outline, but also the more intangible graces of animation and expression possessed by the models from which they were copied. The explanation of his not having made the operations of the machine more widely known at an earlier period, is doubtless to be found in the principle he announces in one of his letters to Mr. Magellan, "I "never choose to publish anything which is not "complete."* And such completeness as he required went far beyond the ordinary requirements even of the greater number of other accurate and able men.

Those who have witnessed with wonder the perfect truth of the numismatic and artistic fac-simile engravings which by similar glyptic machines a Bate and a Collas have in later days produced; or the economical multiplication of carvings of the most varied and intricate designs,

* 16 Oct., 1780.

which by the mechanical resources of the present day have been placed within the reach of nearly all who desire to possess them; or the still more admirable and elevated art by which the works of a Cheverton can boast of repeating those of a Canova, a Thorwaldsen, or a Chantrey; may feel interested in becoming acquainted with the results that in the earlier part of the present century were not only theoretically planned but practically attained by the sagacious thought and skilful hand of Watt.

Only one problem, indeed, seems now to remain for such means to achieve; that, viz. of at once copying from the living model, in materials of lapidary hardness. For hitherto, in the object to be copied an inflexible surface has always been requisite, to enable the guiding point of the machine to traverse it with firmness. But even this appears to be a difficulty which may in time be overcome; possibly by the *power* being applied solely to the cutting tools, but their direction being regulated by a guiding-point delicately moved over a soft surface, or even in air. It is, perhaps, neither to be expected nor desired that such a process, which, however exact, must still be entirely mechanical, should ever supersede the freedom of inspiration which breathes in the works of a Praxiteles or a Phidias; any more than that the angelic grace of a Raphael or a Correggio, or the glorious colouring of a Titian or a Guido, should be eclipsed by the photographic results of the mere chemical action of light and a combination of optical media. But such me-

chanical and philosophical contrivances no doubt offer some additional facilities to the study and attainment of the highest pictorial art; and certainly, as the means of at once encouraging and gratifying some measure of artistic taste in millions of human beings who must otherwise have been destitute of such innocent and rational enjoyment, their inventors deserve at once our respect and our gratitude.

The classical "garret" and all its mysterious contents,—the Polyglyptic Parallel-Eidograph with its tools and models included,—have ever since been carefully preserved in the same order as when the hand and "eye of the master" were last withdrawn from them, and he crossed the threshold never to return to his work on earth. When lately inspected by us,* all things there seemed still to breathe of the spirit that once gave them life and energy; and only the presence of some reverend dust silently announced, that no profane hand, forgetful of the "religio loci," had been permitted to violate the sanctities of that magical retreat, or disturb the repose of the "wheels," and "drills," and "guiding-points," that have never since been moved.

* In 1853.

CHAPTER XV.

MR. WATT'S PURSUITS IN RETIREMENT — HIS POLITICAL SENTIMENTS — ANECDOTES OF HIS SON JAMES — CHARACTERISTICS OF MR. WATT'S CONVERSATION AND FRIENDLY COUNSELS — JEFFREY — SCOTT — MADAME LAVOISIER — T. CAMPBELL — LORD BROUGHAM.

SUCH were some of the mechanical recreations in which the aged engineer was wont to employ the moderate strength, and the unalterably inventive thoughts, which were still granted to him; blending with them, when at home, the pleasures of horticulture, of happy social intercourse with his neighbours, of most various study, and even of *novel-reading*,—with him always a favourite department of literature! When he occasionally visited London, he lost no opportunity of making himself practically acquainted with every new discovery or contrivance of merit, of which any report had reached him: on the ingenious wonders so abundantly exhibited in the shop-windows of the metropolis, he gazed with all the delight of a child; and it often happened that their owners, after leading him into conversation, and finding themselves far surpassed in knowledge of their own peculiar pursuits, felt as though they had "entertained an angel unawares." The orbit of his movements, in short, always bright with his

own light, was also marked, long after the period of his passage, by what M. Arago has so characteristically termed "luminous traces."

Sometimes, during the last quarter of a century of his life, he gave to his journeys a somewhat wider geographical range. In 1802, when, during the peace of Amiens, the Continent was for a brief season opened to British travellers, he once more visited Paris; where he renewed his acquaintance with those of his former scientific friends whom time, and the crimes of the revolution, had spared. He also frequently amused himself with tours of observation and enjoyment throughout England, Scotland, and Wales; as well as with agricultural pursuits, and various rural improvements, on several farms in the latter country. There the beauty of the scenery, uniting the softness of the south with some of the wild grandeur of the north, induced him gradually to make several purchases of land. He began that species of investment in 1798, at first on a small scale; and some of the parcels of land which he at first bought were rather widely scattered; but many of them, with large additions made by his son, now form an extensive estate, the greater portion of which is situated in Breconshire and Radnorshire, between Rhayader and Newbridge, on the most charming part of the course of

"The sylvan Wye, that wanderer through the woods,"

and of the Ithon, one of the most picturesque of its tributaries.

The simple, but neat and comfortable farmhouse of Doldowlod, (of which the greater portion yet remains, although now overtopped by another mansion, of greater pretension, lately erected by its side, and communicating with the more modest cottage of earlier days), was the home which congenially received him on his occasional visits. The fine woods which there richly clothe the valley, and agreeably diversify the river and mountain scenery, were chiefly planted under his superintendence and direction;—very many of the trees by his own hand. But, if he thus incurred one portion of the reproach attached by the historian to all who are addicted "agro colendo, "aut venando, servilibus officiis intenti, aetatem "agere," * he was at least exempt from the other; for, unless we except the metaphor by which he announced his first glimpse and pursuit of the "parallel motion," viz. "I have started a new "hare," † we have not been able to find even the remotest trace of his having, at any time of his life, partaken of the healthful delights to be found in following the sports of the field. ‡

* Sall. Bellum Catil., cap. iv.

† To Mr. Boulton, 30 June, 1784. See vol. ii., No. [258], p. 191, *infra*.

‡ In all that concerned the acquisition and beneficial management of their Welsh property, both Mr. Watt and his son derived very material aid from the enlightened judgment and great ability of Mr. James Davies, of Moorcourt in Herefordshire; a gentleman whose services to his own and two neighbouring counties have already been sensibly felt and splendidly acknowledged by their inhabitants. His good memory, indeed, can scarcely fail to descend to posterity along with that of "the man of Ross," unless for a reason which did not

It is right that we should here authoritatively vindicate the venerable subject of our biography from the allegation,—which, however, in these days of rapid political conversion it might be somewhat unsafe to call the *reproach*,—of having been what is termed "a sad radical." There never was a more unfounded impression formed of any man's political sentiments than this; for the wise engineer was throughout his life possessed with the most loyal and constitutional principles; having been, in truth, a plain and homely, but honest and steady *Tory*, of what is called, not without strong reason, and by way of contrast, we suppose, to some modern innovations, the good old *consistent* school. "Our principles," he says, when describing the riots at Birmingham in 1791 and the threats held out by the mob, "which are well "known as friends to the established government "and enemies to republican principles, should have "been our protection from a mob whose watch-"word was *Church and King*;" and he uniformly expressed his horror at the proceedings of the revolutionists in France, as well as of the unbridled sovereignty of the people in any country. So clear and decided, indeed, were his convictions on such matters, that we should scarcely have thought it necessary to allude to them, had it not been that a prime minister of England was understood to have given utterance, previous to the

exist in the case of Mr. Kyrle,—(but which the present humble notice may do little to avert), viz.—"*caret quia vate sacro.*"

close of Mr. Watt's life, to the erroneous doctrine already referred to; and we have ourselves, in the present day, heard the same creed repeated by a very able and usually most accurate person, who, however, was on this point no better informed than the Earl of Liverpool had been.

The truth is, that both of those gentlemen, and any others who may have shared their opinion on this subject, led astray by the similarity of name, have confounded Mr. Watt as a politician, with his son Mr. James Watt; who certainly was in his youth carried away, by the enthusiasm then prevalent in what was termed the cause of liberty, to sympathise with the Girondins and Jacobins in Paris, and even to take some open and avowed part in their earlier tumultuous agitations. He was for some time, in company with Thomas Cooper, and Wordsworth the poet, in the habit of associating with many of those men who afterwards attained a dreadful celebrity; and, as Southey has mentioned, was at that time the means (unfortunately for the world!) of preventing a duel between Danton and Robespierre.

"Danton and Robespierre," says Southey, "quarrelled at one of the political clubs, before "the 10th of August: high words ended in a "challenge: they met, and the duel was pre-"vented by the interference of an Englishman, "who went out as a second to the one, and re-"presented to them how injurious it would be to "the cause of liberty if either of them should

"fall. (!) That Englishman was the present "James Watt of Soho, and from him I heard this "remarkable fact." *

For another more public exhibition of mistaken zeal displayed in the same cause, Mr. James Watt, jun., and his clever, but eccentric friend Cooper, were thus severely denounced in the British House of Commons:—"Messrs. Cooper "and Watt," said Burke, in the debate on Mr. Sheridan's motion relative to the existence of seditious practices in this country,† "had pre- "sented an address, and carried the British "colours in a procession; and on what occasion? "The most infamous that ever disgraced the name "of government. A set of soldiers had been tried "by a court-martial, and condemned to the galleys. "These were fit men for the republicans of Paris. "They might be useful:—though bad soldiers, "they might be good murderers. They were "released in contempt of the Assembly then "sitting; brought to Paris, and paraded in "triumph through the hall. On this detestable "occasion, Mr. Cooper and Mr. Watt carried "the British colours. They were locked in the "fraternizing embrace. They received the fra- "ternizing kiss. They went from the hall of the "Assembly to the hall of the Jacobins, where they

* See letter from Southey to A. Alison, Esq. (now Sir Archibald Alison, Bart.), Keswick, April 17, 1833. 'Life of R. Southey,' by Rev. C. C. Southey, vol. vi. p. 209.

† March 4, 1793.

" kissed the bloody cheek of Marat;—the iron " cheek of Pluto instead of Proserpine;—

> " What ardent transports through their bosom ran,
> " Clasp'd in the embraces of the godlike man!" *

The first blood of citizens, however, which the young political enthusiast saw spilt in the gardens of the Tuileries and streets of Paris, sickened him of that "license" which those wretches meant "when they cried liberty;" and he then endeavoured to mitigate as far as possible that violence of revolutionary rage which he foresaw he must in future deplore.

This partial change of sentiment led to a curious result; for Robespierre having then insinuated in one of his addresses at the Club of the Jacobins, that Cooper and his compatriot were emissaries of Pitt, Mr. J. Watt, with the same fearlessness with which he had previously supported a cause which he imagined to be just, took an instant opportunity of confronting that monster in his own arena;—he indignantly sprang on the tribune, from which by main force he ejected the truculent orator, and in a brief but impassioned harangue, delivered in French, which he spoke with perfect fluency and an excellent accent, completely silenced his formidable antagonist, carrying with him the feelings of the rest of the audience, who expressed their sense of his honest British spirit, in a loud burst of

* Speeches of the Right Hon. Edmund Burke, vol. iv., p. 124, ed. 1816.

applause! On returning home, having learned, by sure intelligence from one deep in the secrets of his dangerous foe, that his life was no longer safe for a day, he instantly quitted Paris, without even a passport. He succeeded, though with some difficulty, and occasionally at great hazard, in making his way to the south, and never rested till he arrived in Italy. There having devoted himself to other pursuits than politics, and his revolutionary ardour having had time to cool, he saw good cause to shudder at the atrocities committed by those who so lately had been his chosen companions.

"I went over to Paris,"—said the late poet Wordsworth to us, in one of those hours which his presence and converse winged with unfailing delight,—"at the time of the revolution in 1792 "or 1793, and so was *pretty hot in it*; but I found "Mr. J. Watt there before me, and *quite* as warm "in the same cause. We thus both began life as "ardent and thoughtless radicals; but we have "both become, in the course of our lives, *as all* "*sensible men, I think, have done*, good, sober-"minded Conservatives!"

Such, however, is no doubt the true explanation of the politics of Mr. Watt, senior, having ever been mistaken. But although his own views were uniformly such as we have stated, even he, in judging of those of others who differed from himself, seems to have exhibited all that philosophical moderation which so strikingly characterised his habitual sentiments: as when speaking of Pro-

fessor Robison he says,—"he entertained a high "respect for the constitution of his country, and "detested the novel doctrines of Jacobinism which "made him pass *censures too severe upon several of* "*the French philosophers, (otherwise extremely esti-* "*mable men, and to whom science is much indebted),* "*without duly weighing the circumstances in which* "*they were placed.*" *

That the intellectual pleasure derived from the society and conversation of Mr. Watt was of the very highest order, the united testimony of his most intimate friends and associates sufficiently proves. "It was no wonder," as Robison observed of an earlier stage of his life, "that the attach- "ment to Mr. Watt was strong, when persons of "every taste and every pursuit found in him an "inexhaustible fund of instruction and entertain- "ment." Men of all ranks shared freely in the benefits of his counsels, as well as in the enjoyment of his cheerful cordiality; and alike to the humble artisan as to the aristocrat of rank and talent, the winged hours flew fast in listening to his words of wisdom, delivered in the guise of easy, social, unassuming converse. To the very close of his life, this light of his burned steadily and brightly; —he was constantly applied to by those,—(and their name was legion),—who either had invented, or imagined that they had invented, mechanical contrivances of any novelty or utility; and who naturally wished either to obtain the criticism of

* See vol. ii. No. [353], p. 299, *infra*.

so experienced a judge, or to bespeak his favour and encouragement.

Some letters, such as those at pp. 270-271, and 315-317 of vol. ii., are given as instances of the great candour and condescending kindness with which he usually took pains to caution such persons against their over-sanguine expectations, and also to explain to them some fundamental principles in mechanics, which they too often had overlooked; but which lay, perhaps, at the very threshold of their inquiries, and, if duly considered, might, by stopping their further progress in a particular direction, save much subsequent disappointment, and loss of both time and money. To the extravagant vagaries which occasionally were suggested to him by such projectors, there really were no limits; as when one author, in forwarding to him what he calls his "book on philosophy," observed:—"If the popular or Newtonian system "of causes of mundane phenomena and motions "are facts, and things are actuated by them as "principles, I really am not constituted to hear, "see, feel, or comprehend like other persons." A conclusion of the learned writer, the justice of which, (although not exactly the sense in which he intended it), probably none of our readers will be disposed to deny!

"His friends in that part of the country," says Lord Jeffrey, speaking of a visit which Mr. Watt paid to Scotland, when upwards of eighty, "never "saw him more full of intellectual vigour and "colloquial animation, never more delightful or

"more instructive." * It was then also that Sir Walter Scott, meeting him "surrounded by a "little band of Northern literati," saw and heard, —what he felt he was never to see and hear again,—"the alert, kind, benevolent old man, his "talents and fancy overflowing on every subject, "with his attention alive to every one's question, "his information at every one's command." †

The rest of that description it is needless to give here; for, in all its gay and charming exuberance, it is known wherever the name of Scott is hallowed. But a passage of kindred interest, and, although less commonly adverted to, scarcely, we think, less striking to those who study *the manners of great minds*, occurs in Mr. Lockhart's Life of his illustrious connection, where he says, "Scott never considered any amount of literary "distinction as entitled to be spoken of in the "same breath with mastery in the higher depart- "ments of practical life. * * To have "done things worthy to be written was, in his "eyes, a dignity to which no man made any ap- "proach who had only written things worthy to "be read. He on two occasions, which I can "never forget, betrayed painful uneasiness when "his works were alluded to as reflecting honour "on the age that had produced Watt's improve- "ment of the steam-engine, and the safety-lamp

* See 'Character of Mr. Watt, by Lord Jeffrey,' Appendix to Translation of Arago's Eloge, p. 181, ed. 1839.

† Introduction to THE MONASTERY, Abbotsford edition, vol. v., pp. 29, 30.

" of Sir Humphry Davy. Such was his modest " creed." *

We believe that Sir Walter could not possibly have felt a more profound reverence for the mighty labours of the great mechanical engineer than Mr. Watt did for the magical powers of the glorious novelist and poet. Probably each entertained towards the works of the other sentiments of greater wonder, and no less affection, than towards any of the more familiar creatures and combinations of his own imaginative or inventive brain. We know not, indeed, whether, if the general suffrages of mankind could be collected as to the respective objects of the two sorts of ambition, the result might not, in the present age, be the converse of that at which Scott seems to have arrived.† But when the exertion of literary power is supported by sound learning, and the exercise of practical art is regulated by the standard of accurate science; when each is employed with such signal success to instruct, to refine, to improve the condition and extend the happiness of mankind; when thus both fairy fiction and stubborn facts are seen alike to be—

" —— ministers of *Truth*,
" And feed her sacred flame :"——

the balance of comparative merit seems to hang

* 'Lockhart's Life of Scott,' chap. xxxv. p. 322, ed. 1842.

† " Et qui fecere, et qui facta aliorum scripsere, multi laudantur. Ac " mihi quidem, tametsi haudquaquam par gloria sequatur scriptorem et " auctorem rerum ; tamen *in primis* arduum videtur *res gestas scribere*." Sall. *Bellum Catil.* cap. iii.

wonderfully even, and the meed of consequent fame which the voice of posterity confers, to be awarded in, probably, a very equal measure.

Among the many "celebrities" who, in the last years of its master, visited the retirement of Heathfield, (a small estate near Birmingham and Soho, which Mr. Watt had purchased in 1789), was the Countess Rumford, with whom, as Madame Lavoisier, Mr. Watt had made friendly acquaintance on his first visit to Paris. It is curious to observe how much scientific history of "'tis sixty "years since," is epitomised in that lady's surrender, and subsequent transfer, of her affections; as well as in one, at least, of her intermediate refusals so to transfer them. In the dawn of her youth and beauty she was happily married to Lavoisier, and, in the noon-tide of his great reputation, made more than half the charm of his delightful home. But that tie having been too early severed by his dreadful death at the hands of the Revolutionists, she chose to marry, "en "secondes noces," Thompson Count Rumford, and did *not* choose to marry Dr. Blagden. "Cavendish," says Lord Brougham, "having "formed a high opinion of Dr. (afterwards Sir "Charles) Blagden's capacity for science, settled "a considerable annuity on him, upon condition "that he should give up his profession and de-"vote himself to philosophy; with the *former* "portion of which condition the Doctor complied, "devoting himself to the hopeless pursuit of a "larger income in the person of Lavoisier's

" widow, who preferred marrying Count Rum-
" ford." *

" Watt himself," says Thomas Campbell, 'the 'Bard of Hope,' writing in February, 1819, " is " now eighty-three, but so full of anecdote that I " spent," (in his company at Heathfield), " one of " the most amusing days I have ever had with a " man of science and a stranger to my own pur-
" suits." † This is not the only relic which Campbell has left us of his visit to Heathfield and the Soho works; for in a little poem which is published in his Life by Beattie (vol. iii., p. 101), he follows the example which Darwin had set him, of marrying to immortal verse the somewhat unpoetical performances of the steam-engine :—

" Whirl'd by the steam's impetuous breath
" I mark'd yon engine's mighty wheel,
" How fast it forg'd the arms of death,
" And moulded adamantine steel!

" But soon—that life-like scene to stop,—
" The steam's impetuous breath to chill,
" It needed but one single drop
" Of water cold, and all was still!

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* 'Lives of Men of Science and Letters,' vol. i. p. 445, ed. 1845.

Lord Brougham adds, that a legacy of 15,000*l.* bequeathed to Blagden by Cavendish, (see Mr. Watt's Correspondence on his Discovery of the Composition of Water, p. lxxvii., 1846), " was generally " understood to have fallen much short of his ample expectations." Perhaps it failed to the same extent to console him for the Lavoisier loss; although on that head he may possibly have recollected the observation of a great master of the angling art to his scholar,—" Nay, " the trout is not lost; for pray take notice, no man can lose what he " never had."—' The Complete Angler, or Contemplative Man's Recre-
' ation, by Izaak Walton,' p. 104, ed. J. Major, 1823.

† Beattie's 'Life of Campbell,' vol. ii. p. 345.

" Even so, one tear by * * shed,
" It kills the bliss that once was mine ;
" And rapture from my heart is fled,
" Who caus'd a tear to heart like thine !"

And in the summer of the same year, Lord Brougham found his instructive conversation, and his lively and even playful manner, unchanged.*

* 'Lives of Men of Science and Letters of the Reign of George III.,' vol. i. p. 385.

CHAPTER XVI.

MR. WATT'S LOSS OF FRIENDS BY THEIR PREDECEASE — HIS OWN LAST ILLNESS — AND DEATH — MONUMENTS TO HIS MEMORY — WESTMINSTER ABBEY — HANDSWORTH CHURCH — GLASGOW — GREENOCK — PORTRAITS, STATUES, AND BUSTS.

No shade, indeed, seems ever to have passed across the pleasant sunshine of those years of a bright old age, thus prolonged in lustre, save that inevitable one cast by the awful vicissitudes of death and life. But that dread shadow, ever chequering the path of humanity, as some are left a little longer in the "wilderness of this "world," and others are taken a little sooner to their eternal rest, falls most frequently and darkly across the road of him who has the longest journey to make.

In 1794, Mr. Watt had lost his old patron and associate Dr. Roebuck; in 1799, his dear friends Black and Withering; in 1802, Darwin "of the "silver song." Two years later, his darling son Gregory, the charms of whose presence and extraordinary talents were the ornament and pride of his race, languished and died of that insidious disease which so often destroys the most accomplished and the most lovely; and it was long ere

the old man's feelings recovered their wonted tranquillity, which this severe blow had deeply disturbed. The loss of his early and ingenious companion Professor Robison in 1805; of Dr. Beddoes in 1808; of Mr. Boulton in 1809; of Dr. Patrick Wilson in 1811, and of De Luc in 1817 (at the great age of 93),* as well as of many others who, though less known in the fields of science, were not less honoured by his cordial attachment, caused him emotions of sorrow to which he has repeatedly given utterance. But such events were calls to him also to be ready, and such calls he habitually acknowledged and obeyed. And when, in the autumn of 1819, an illness of no great apparent severity,—but which also proved to be of no very long duration,—caused some little anxiety to his friends, it was soon recognized by himself, with devout resignation, as the messenger sent to summon him away. In contemplation of the solemn event which he perceived was certainly approaching, he calmly conversed on that and other subjects with those around him; and expressed his gratitude to the Giver of All Good, who had so signally prospered the work of his hands, and blessed him with length of days, and riches, and honour.

On the 19th of August, at his own house at

* On what appears to have been Mr. Watt's last visit to him at Windsor, in July, 1811, he says he saw "poor Mr. De Luc, who can-" not stir from his bed without help, but can sit and write, in which " he occupies himself constantly. His memory and faculties seem " entire. * * His present work is an account of his travels on the " coasts of the Baltic."

Heathfield, he tranquilly expired; and, amid the reverent sorrow of all classes of men, his remains were interred in the parish church of Handsworth, near those of his eminent and venerable associate, Mr. Boulton.

The tribute which a grateful nation has since paid to his memory is testified not only by those other monuments which in other places throughout the kingdom his countrymen have set up; but also by the colossal statue, from the chisel of Chantrey, erected in Westminster Abbey, by "the King, "his Ministers, and many of the Nobles and "Commons of the land;" "NOT," in the eloquent words of Lord Brougham, now for ever associated with the triumphs of the sculptor, "TO "PERPETUATE A NAME WHICH MUST ENDURE "WHILE THE PEACEFUL ARTS FLOURISH, BUT "TO SHOW THAT MANKIND HAVE LEARNED TO "HONOUR THOSE WHO BEST DESERVE THEIR GRA-"TITUDE."

The filial piety of the late Mr. Watt of Aston Hall has liberally and judiciously multiplied those noble statues of his father, which have been justly regarded as Chantrey's greatest works. Thus the Town of Greenock, the University of Glasgow, and the Church of Handsworth, each possesses one of those exquisite pieces of memorial sculpture, truthfully portraying to distant ages the mild, thoughtful, and venerable features of the patriarchal sage, and with silent but impressive eloquence commemorating the birth, the life, the inventions, and the death of James Watt. There

is, perhaps, no one whose name more forcibly illustrates the sentiment of antiquity,—that "of "illustrious men the whole world is the tomb; "and not only does the inscription on their own "monuments in their own country bear witness "to their glory, but even in foreign lands an "unwritten record of the mind rather than of any "monument remains with every one for ever."*

To him we may, perhaps, be permitted to apply, —in no spirit, we trust, of undue presumptuousness,—what a loving disciple has said of another of the greatest of sages :—

"This was the end, to us, of our friend: a man "who was, if we may be permitted to say so, of "all those of his time, (so far as we have known "anything of them), THE MOST VIRTUOUS, THE "MOST WISE, AND THE MOST JUST." †

It may be proper to append to this memoir some account of the principal portraits, statues, and busts of Mr. Watt. And first, of the portraits. They are ;—

1. A half-length by Sir William Beechey, painted in 1801, and exhibited at the Royal Academy in 1802. "I this day," says Telford, (3rd May,

* "Ἀνδρῶν γὰρ ἐπιφανῶν πᾶσα γῆ τάφος, καὶ οὐ στηλῶν μόνον ἐν τῇ "οἰκείᾳ σημαίνει ἐπιγραφὴ, ἀλλὰ καὶ ἐν τῇ μὴ προσηκούσῃ ἄγραφος μνήμη "παρ' ἑκάστῳ τῆς γνώμης μᾶλλον ἢ τοῦ ἔργου ἐνδιαιτᾶται."—Thucyd. lib. ii. cap. 43, ed. Arnold, 1830.

† "Ἥδε ἡ τελευτή, ὦ Ἐχέκρατες, τοῦ ἑταίρου ἡμῖν ἐγένετο· ἀνδρός, ὡς "ἡμεῖς φαῖμεν ἄν, τῶν τότε ὧν ἐπειράθημεν ΑΡΙΣΤΟΥ, καὶ ἄλλως ΦΡΟΝΙ- "ΜΩΤΑΤΟΥ, καὶ ΔΙΚΑΙΟΤΑΤΟΥ."—Plat. *Phæd.* cap. lxviii.

1802), "paid my respects to you in the Exhibition "room. I think Beechey has succeeded admirably "well."* In 1809 Mr. Watt wrote to one of his friends, "There is no good portrait of me except "that painted by Sir William Beechey, still in his "possession, and a copy of it by himself in Mr. "Tuffen's collection, which is more like than the "original, I having sate again for it. Neither of "them," he adds, "is esteemed very like by my "son and others." † On this point his son afterwards rather changed his opinion; and, indeed, came to prefer the portrait in question to any of the other paintings of his father. It may be remembered by many of his friends as having formerly hung in the dining-room at Aston Hall, and is now at Doldowlod, Radnorshire. It has been twice engraved.

The copy which belonged to Mr. Tuffen was, we have ascertained, not included among the pictures belonging to that gentleman which were sold by auction at Christie's in 1818; and we believe it to be the same that is now in the possession of Charles Hampden Turner, Esq., of Rook's Nest, in Surrey, to whom it was presented by the late Mr. Watt.

2. A miniature enamel by Bone, taken from Sir W. Beechey's portrait in 1805, and executed with all the usual fidelity and success of the artist, so eminent in a line in which few have been

* Mr. Watt to Dr. Patrick Wilson, 22 May, 1809.
† Mr. Telford to Mr. Watt, 3 May, 1803.

able to attain excellence. Size 8×6½ inches. At Doldowlod, Radnorshire.

3. A three-quarter, or head size, in crayons, or *pastel*, by Longcastre, an emigrant officer of the Guards of Louis XVI., who was introduced to Mr. Boulton in 1805 by their mutual friend the Abbé de Calonne. Of this, which is a striking portrait and exact likeness, there is a duplicate by the same artist. One of the pair was presented by Mr. Watt to his cousin Mr. Robert Muirheid, and is preserved at Ashcraig, in Ayrshire; the other, which was executed for Mr. Boulton, and long hung in his house at Soho, is now at Haseley Court, Oxfordshire.

4. A three-quarter, or head size, by Partridge, painted (in oils) from Sir W. Beechey's portrait, and also from additional sittings. This good and pleasing likeness was presented by the late Mr. James Watt, junior, to Mr. Barr, the respected medical attendant of his father in his last illness. By him it was bequeathed to the late Dr. John Smith, of Crutherland, in Lanarkshire; on whose death it was sold by auction, and purchased by the Rev. Dr. Fleming, of Glasgow College; who again transferred it to Mr. Robert Napier, the eminent engineer. In his possession, we believe, it now remains.

5. A "bishop's half-length," by Sir Thomas Lawrence, exhibited at the Royal Academy in 1813. This noble work of art, although for some reason or other it seems not to have found due favour in the sight of either Mr. Watt or his son,

stands, in our opinion, unrivalled among all the portraits of Watt. It was so great a favourite with the artist who had painted it, that after retaining it for years in his studio, he at last did not part from it without much reluctance. He considered the head *the finest he had ever painted:* the ease of the attitude, and the drawing and flesh-tints of the hands, are also wonderfully beautiful and true to nature. The posture is sitting; the head slightly bowed with age; the eyes are looking full at the spectator; the hair is silver-white,—(Mr. Watt was then in his seventy-eighth year;)—the expression of the countenance is animated, yet calm, mild, and thoughtful. This portrait was bequeathed by the late Mr. Watt, of Aston Hall, to his god-son Matthew Piers Watt Boulton, "to "be by him preserved in his Gothic Library, at "Tew Park, along with the portraits of his late "grandfather and father, and to accompany those "portraits as heir-looms in his family." It has been engraved in mezzotint by Mr. Charles Turner, but impressions of the plate are rare.

6. A three-quarter, or head size, by Sir Henry Raeburn. Neither Mr. Watt, nor his son, having felt perfectly satisfied with any of the portraits previously painted of him, he sat for this when in Edinburgh in November, 1815, being then seventy-nine years of age. "Raeburn," he says, "has "painted a head of me, which, though it does not "come up to my ideas of my own face, is more "conformable to them than any of the others, and "by my friends is said to be a good likeness."

And again, "My Edinburgh picture is come home, "and is thought like, only it frowns too much." This portrait, of which a copy was made by the artist, with Mr. Watt's full approval, for his friend the late Mr. Rennie, is now at Heathfield, and is a finely coloured and forcible picture.*

7. A three-quarter, or head-size, by Mr. J. Graham Gilbert. "Taken," says the artist, "from "Chantrey's bust and Sir Thomas Lawrence's "portrait." Mr. Gilbert presented this work to the Hunterian Museum in the University of Glasgow, where it now hangs; and he has furnished us with a strong proof of his success in producing a likeness in the anecdote that "when "Mrs. Watt saw the portrait in the Museum, she "thought it so like, that she immediately ordered "one precisely the same for herself; which was

* The finest works of Raeburn need not fear comparison with those of any artist of modern times, and do the highest honour to that country which produced a Jameson, "the first true portrait-painter of "the isle." "Raeburn," says the biographer of Wilkie, "even while "Wilkie studied in Edinburgh, stood at the head of his art in the "North, undisturbed by a rival. His style was manly and vigorous; "he entered little into the detail of the face, but called the mind into "the countenance, and fixed it there with a happiness of expression in "which he found few who shared. He lived in affluence and hos-"pitality, visited and dined among the first-born of the land, and had "a residence and a gallery of a splendour new to Scottish art." (Life of Sir David Wilkie, by Allan Cunningham, vol. i. p. 56.) "There is "much resemblance," said Wilkie himself, "between Velazquez and "the works of some of the chiefs of the English school; but, of all, "Raeburn resembles him most,—of whose square touch in heads, "hands, and accessories, I see the very counterpart in the Spaniard." (*Ibidem*, vol. ii. p. 504. See also Sir Edmund Head's Handbook of Painting of the Spanish Schools, p. 155, ed. 1854.)

"lately,"—(we can add that it still remains),—"at her place [Heathfield] near Birmingham."

In 1809, Mr. John Henning of Edinburgh made a large chalk drawing of Mr. Watt, (a head), for the late Lord Jeffrey, as well as a small copy of it for another gentleman; also two or three enamel casts on an enamel ground, made in a furnace, and intended, we presume, to emulate the excellent works of Tassie in that style. The smaller drawing we have never seen; of the larger one, which is still preserved in Edinburgh, and of which some of the features possess considerable likeness to those of Mr. Watt, the general effect is, nevertheless, heavy, and not very pleasing. The same may, we believe, be said of the enamel casts.

In 1818, J. Jackson, the Royal Academician, made a drawing of Mr. Watt from sittings, and also one from Chantrey's bust; the former was thought creditable to him as an Exhibition drawing. It is a sketch in pencil, on drawing paper, front view, with the face carefully finished in water-colour; size, $8\frac{1}{2} \times 6\frac{1}{2}$ inches. As was to be expected from the well-known powers of the artist, it is a clever and forcible drawing; but the expression is, as Mr. Watt observed, rather "peevish," and, therefore, unpleasant. It is now at Doldowlod.

The most pleasing pencil drawing of Mr. Watt, which at the same time possesses the greatest resemblance, is, singularly enough, one that was made not from the life, but from Chantrey's bust, by an artist, Mr. Edward Finden, who, (so far as

we know), never saw Mr. Watt. This spirited sketch was engraved by Mr. Finden with equal success, and forms the frontispiece to the present volume. It has already appeared with the Translation of M. Arago's 'Eloge,' in 1839, as well as with the 'Correspondence on the Discovery of 'the Composition of Water,' in 1846; being, of all the engravings of his father, that by which the late Mr. Watt wished that his image should be conveyed to posterity:—a reason which the Editor trusts will be accepted as a sufficient apology for the somewhat unusual repetition of the same engraving in three successive works.

The full-length statues of Watt, by Chantrey, are five in number. Two of them are of colossal size: the one, of marble, in Westminster Abbey; the other, of bronze, in George's Square, Glasgow. The other three, those, viz. in Handsworth Church, Glasgow College, and Greenock Library, are of the size of life. In all, the well-known attitude, (a sitting one), the arrangement of the drapery, and the contemplative expression, are nearly alike; and they all are eminent examples of that truthful style of portrait-sculpture for which the master who modelled them was so remarkably distinguished. But in point of success in conveying the expression of gracious ease, and of the mild yet thoughtful repose of a deeply-fathoming intellect, the preference must, it is usually confessed, be given to those which are not colossal. Of the three others, that in Handsworth Church appears to us to impress the spectator most strongly with the blended majesty and sweetness

which breathed in the features of the original. Independent of its own exquisite grace as a work of art, it is also seen to the greatest advantage, in a chapel built expressly for its reception and preservation, in which the details of space, elevation, and light were all carefully adapted to the designs and wishes of the sculptor. And it adds in no small degree to the feeling of solemn interest of which all are conscious in beholding so noble a monument, to learn that in the vault beneath repose the remains of him who, while he lived among us, "SIC SEDEBAT."

Of the beautiful marble busts of Mr. Watt by Chantrey, the first of which was exhibited at the Royal Academy in 1815, and in finishing which the sculptor said, "I have done the best in my "power," we have seen seven; besides three others, scarcely inferior, completed, after the death of Sir Francis, but from his model, and with the consent of his executors, by his very able assistant Mr. Heffernan.

From a mould which Chantrey made of the bust, he took several good casts, which were chiefly distributed by Mr. Watt and his son among their personal friends. But, as in the case of Sir Francis's equally fine model of the head of Sir Walter Scott, "the bust was pirated by Italians; "and England and Scotland, and even the "Colonies, were supplied with unpermitted and "bad casts, to the extent of thousands,—in spite "of the terror of an Act of Parliament." * On

* Sir F. Chantrey to Sir R. Peel, 26th January, 1838. Lockhart's Life of Scott, chap. lxxxiv. p. 763, ed. 1842.

receiving one of the genuine casts, fresh from the atelier of Sir Francis, Sir Walter Scott wrote to Allan Cunningham,—"I have to thank you for "sending me in safety a beautiful specimen of our "English Michael's talents, in the cast of my "venerable friend Mr. Watt: it is a most striking "resemblance, with all that living character which "we are apt to think life itself alone can exhibit."*

When the Art-Union employed the late Mr. Wyon to execute a medal in honour of the memory of Sir Francis Chantrey, the design adopted,—a simple and expressive one,—was, for the obverse, a head of the sculptor, with the legend—

"CHANTREY SCULPTOR ET ARTIUM FAUTOR:"—

for the reverse, a copy of his greatest work. The work selected was the monument to James Watt;—with the inscription—

"WATT
"FRANCISCI CHANTREY OPUS."

The medal was finished by Wyon with all the force and facile elegance of his admirable style, and thus forms a graceful memorial of those whose names it bears.

We must not conclude this notice without referring to some of the most exquisite of all the likenesses of Mr. Watt, viz. the reduced copies of Chantrey's bust which Mr. Cheverton has, with great ingenuity, executed in ivory. They possess the most perfect and truthful adherence to their original, as well as the most finished execution,

* Life of Scott, Chapter l. p. 440, ed. 1842.

that it seems possible to desire; and it gives an additional interest to those beautiful *morçeaux*, that they are produced by a process similar to that which Mr. Watt himself invented.* Indeed, Mr. Watt, in sending to his learned friend the late Mr. Thomas Thomson of Edinburgh, what he calls a specimen of his attempts at carving,—"a wooden "John Locke, *without Human Understanding*, "valuable only as a faithful copy of an ivory "medallion done from the life,"—says, "if I live, "I still hope to be able to produce a reduced copy "of Chantrey's bust of myself, fit for a chimney-"piece;" adding, with a very sincere, but a very unnecessary scruple of his usual modesty,—"as I "do not think myself of importance enough to fill "up so much of my friends' houses as the original "bust does."†

* See above, pp. ccxlii—cclv, on the Machine for Reducing and Copying Sculpture.

† Mr. Watt to Mr. Thomas Thomson, 26th May, 1818.

END OF THE INTRODUCTORY MEMOIR.

EXTRACTS

FROM

MR. WATT'S PRIVATE CORRESPONDENCE.

EXTRACTS

FROM

MR. WATT'S PRIVATE CORRESPONDENCE.

[1.] MR. WATT TO DR. LIND.

Glasgow, April 29, 1765.

DEAR LIND,—I received yours. I sent you, per last week's carrier, a drawing-machine for yourself, and two of the three-guinea kind to dispose of. I will make a larger machine for the Laird;* but it will be dearer, as it puts us out of sorts. I have now almost a certainty of the *facturum* of the fire-engine, having determined the following particulars: the quantity of steam produced; the ultimatum of the *lever engine*; the quantity of steam destroyed by the cold of its cylinder; the quantity destroyed in mine: and if there is not some devil in the hedge, mine ought to raise water to 44 feet with the same quantity of steam that theirs does to 32 (supposing my cylinder as thick as theirs), which I think I can demonstrate. I can now

* "The Laird of Skene," who had "desired to have a drawing-instrument of the best kind, but larger, so as to take a large sheet of paper."—Dr. LIND to Mr. WATT, 27th April, 1765.

make a cylinder of 2 feet diameter and 3 feet high only a 40th of an inch thick, and strong enough to resist the atmosphere; *sed tace.* In short, I can think of nothing else but this machine. I hope to have the decisive trial before I see you. Write me to-morrow what you are about, and if any part of what you have to tell me concerns the fire-engine.

* * * *

[2.] MR. WATT TO DR. ROEBUCK.

Glasgow, August 23, 1765.

* * * *

I have tried my new engine with good success; for though I have not been able to get it perfectly air-tight from its bad materials, yet, immediately on turning the exhausting cock, the piston, when not loaded, ascended as quick as the blow of a hammer, and as quick when loaded with 18 lbs. (being 7 lbs. on the inch) as it would have done if it had had an injection as usual. The moment the steam-cock was opened, the piston descended with rapidity, snifting all the while, though the steam was very weak. On the faith of this I have set about a larger and more perfect model, having now little doubt of its performing to satisfaction. I think I can now solve the reason why the big cylinder does not take so great a charge as the small; but this I refer till meeting. * *
(Indorsed in Mr. Watt's own hand:) "This seems

to relate to the first model, with a brass cylinder 1¾-inch diameter and about 10-inch stroke. If so, the invention was, probably, made in 1765."

[3.] MR. WATT TO DR. LIND.

Glasgow, Sept. 4th, 1765.

* * * *

I have tried my small model of my perfect engine, which hitherto answers expectation, and gives great, I may say greatest, hopes of success (for certainty could not be called hope), in greater model now far advanced; in short, I expect almost totally to prevent waste of steam, and consequently bring the machine to its *ultimatum*. Of this you may inform Mr. Russell, but need not talk of it to anybody else till further success.

* * * *

[4.] MR. WATT TO DR. ROEBUCK.

Glasgow, Sept. 9th, 1765.

(Various experiments and facts, from which he concludes, "That, in proportion as the sensible heat of steam increases, its latent diminishes, so in the steam-engine working with pressures above 15 lbs. must be more advantageous than below it; for not only the latent heat is diminished, but the steam is considerably expanded by the sensible heat, which is easily added.")

[5.] DR. ROEBUCK TO MR. WATT.

Bo-ness, Sept. 13, 1765.

DEAR SIR,—I received both your favours, for which I am much obliged to you. The fact which you relate is so paradoxical, that, if less accurate observers of nature than yourself and Dr. Black had been witnesses of it, I should scarce have given credit to it. If I rightly understand the process, it amounts to this,—that a certain quantity of water converted into steam *in vacuo* will heat a given quantity (of water) to a greater degree than the same quantity of water converted into steam in air, even though the steam in air appears by the thermometer of a greater heat than the steam *in vacuo*. I shall be glad to try the experiment with you, and make our observations on it afterwards. The experiment is favourable for your plan of an engine, and its failing of the other purpose is of less moment.

I shall hope to see you at Kinneil before the end of this month, and hope Dr. Black will accompany you. Please to tell him I have written into Derbyshire, and I shall be ready to construct the furnace whenever he is at Kinneil; the materials and workmen are ready. I am glad to hear you are in such forwardness to make your trial. It is certainly best to press it forward with all speed, whether you pursue it as a philosopher or as a man of business.

You will please to let me see you as soon as you

are at leisure, and Mrs. Watt can spare time, to whom please to make my compliments acceptable, in which Mrs. Roebuck joins me.

I am, dear Sir,
Your affectionate humble servant,
JOHN ROEBUCK.

The microscope is safe arrived, and affords fine amusement; but Mrs. Roebuck desires me to remind you of the guitar.

* * * *

[6.] MR. WATT TO DR. ROEBUCK.

Glasgow, October 2d, 1765.

(With calculation of experiment on old engine: diameter of boiler, 16 feet; area, 202 feet; diameter of cylinder, 32 inches; length of stroke, $5\frac{1}{5}$ feet; steam used each stroke, $125\frac{4}{5}$ solid feet; steam produced per minute, 1454 cubic feet; strokes per minute, $11\frac{1}{2}$, &c. Indorsed in his own hand: "This relates to an experiment on one of Dr. R.'s common engines, and served to show the great waste of fuel and steam.")

[7.] MR. WATT TO DR. ROEBUCK.

Glasgow, 11 Oct. 1765.

I have made a trial of my machine. It has not entirely answered my expectations, though it has no fault but what I think I can cure. The principal one, and I believe the only one, was the

untightness of the piston, which I think I have found a remedy for. However, I am certain its consumption of steam will be extremely small, and the condensation quick enough; and it may possibly be some days before I can come to you, as I must remedy everything before I send it away.

* * * *

[8.] MR. WATT TO DR. LIND.

Glasgow, Oct. 12, 1765.

* * * *

I have been making trial of my machine, but have not got the piston steam-tight yet; but hope I shall accomplish it. My error was applying the □ piston to it, it being more proper for purposes where the piston is drawn against the pressure than for engines where it flies from it.

I now conceive this to be the best for it, as the cloth has a great latitude to adapt itself to a bad cylinder, and, if the steam goes past one of the rings of cloth, the other will take it up. I am at present quite barren on every other article, my whole thoughts being bent on this machine; so I can write you nothing else, but I remain yours,

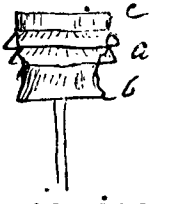
J. WATT.

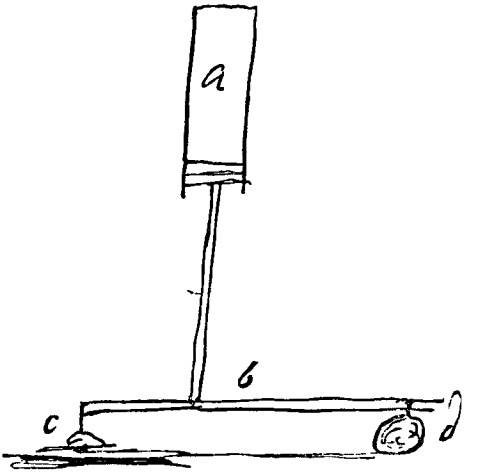
[9.] MR. WATT TO DR. ROEBUCK.

Glasgow, Oct. 16th, 1765.

DEAR DOCTOR,—On repeated trials of my machine I have had better success; it readily works

with 10½ lbs. on the inch, and sometimes I made it lift 14 lbs. I still propose improvements on my piston, with which I am confident it will succeed to my utmost expectations. This is my present piston. At *a* are two collars of varnished cloth; *b* is the old part of the piston, which was made for Belidor's piston, and now remains naked. I propose adding another collar at *c*, and another somewhere on *b*, with which additions I hope it will be perfectly tight, as you will easily see that the addition of a collar increases the tightness vastly. As to the steam consumed it is very little; my little boiler fills the cylinder in less than half a second after it has been ex-





hausted. This is the way in which I tried it: *a* being the cylinder, *b* a lever fastened down by

one end at *c*; *d* is a weight, which, by being moved backwards and forwards, determines the pressure. Now in these circumstances, the weight being in a situation where the engine cannot lift it, and vacuum produced in *a*, it is plain, on opening the steam-cock, the steam will work into *a*, and fill it; to do which, as I said, it took less than half a second, which is known by its opening the snifting valve so soon as it is *in equilibrio* with the air. So soon as the proposed alterations are made I shall forward it to you. I have made some alterations on your *testudo*, and find the ———.* Farewell.

(Indorsed in his own hand: "Inverted engine, with a new piston, the first not answering. The cylinder of this engine was five or six inches diameter, with a two feet stroke; the inner cylinder was made of copper, not bored but hammered, and not very true. It was enclosed in a wooden steam-case, and placed inverted; the piston working through a hole in the bottom of the steam-case. This was the second of my new engines.")

[10.] MR. WATT TO DR. ROEBUCK.

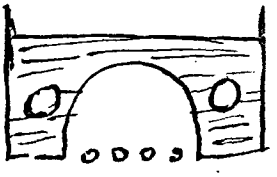
Glasgow, Oct. 18th, 1765.

I was obliged to break off in the midst of my last. I was telling you that the best performance of the testudo was evaporating 25 lbs. of water with about 4 lbs. of coals in about 44 minutes from the time of boiling. In some circumstances

* The letter here leaves off abruptly.

it did evaporate sooner, but with greater consumption of fuel; (the coals were very bad.) I have another contrivance that I think will do better, and be easier of execution, and less bulk. I intend to make a model of it at my own expense, and, if ready, bring it to Kinneil. Perfect or imperfect, I will send you the machine next week. I find nothing makes it work so well as a strong expanded steam.

(Indorsed in his own hand and drawing: "Testudo boiler. The grate formed of hollow tubes, filled with water.—J. W. 1808.")



[11.] MR. WATT TO DR. ROEBUCK.

Nov. 10th, 1765.

(Sends detailed drawings and description for a covered cylinder and a piston, to be cast at the Carron works; whole inside length 7 feet, diameter 24 inches, to be made as truly round and equally wide as possible. Indorsed in his own hand: "Drawing of iron large cylinder. This cylinder was never used, but came to Soho, where it lay long; it was very ill bored, and thereby useless, though the best Carron could make.")

[12.] MR. WATT TO DR. ROEBUCK.

Glasgow, Nov. 18th, 1765.

* * * *

I have the pleasure of informing you that I have

discovered a substance that will make the piston extremely air-tight if oiled, and at the same time have little friction: it is pasteboard. I have tried it, and it was almost perfectly tight, with little friction, and does not appear to wear fast. There is no English pasteboard to be had here: the Scotch is made of old paper, the English of old ropes; it is it only that answers; so I wish you would order a cwt. from Edinburgh, and, if not to be had there, by first ship from London.

* * * *

[13.] MR. WATT TO DR. ROEBUCK.

Glasgow, 4 Dec. 1765.

* * * *

I shall, if my foot allows me, be at Carron on Tuesday or Wednesday, or perhaps it may be Thursday next; and as soon as I have given the necessary orders about setting up the engine, shall do myself the pleasure to wait on you.

* * * *

I tried an experiment t'other night convinces me that we shall work to great advantage by a stronger steam. * * (Recounts an experiment of evaporation of alcohol in a flask.)

[14.] MR. WATT TO DR. ROEBUCK.

Dec. 5th, 1765.

* * * *

I should like to know what length the cylinder is come, and whether the pipes came safe to hand,

and if you think they answer. I have some schemes for cheap materials for them. On consideration, I believe it will be best to try our new engine with the common boiler, and wish you would order plates for it. I think they should be of the thinnest kind. If we make it of the common kind it can be much sooner done, and, in case of failure of success, less loss.

* * * *

My old white-iron man* is dead; which makes me at a little loss about the condenser, but expect to find some other tolerable hand to do it. I have altered the plan of it from small pipes to thin interstices between plates: 16 double plates of a foot square, and half an inch asunder, will answer the purpose of 900 pipes of an eighth diameter. This has another advantage, viz. simplicity and greater ease in making. I have also thought on something new about the pump of the condenser, and also for the pump in the pit. Thinking on these things is a kind of relief amidst my vexations.

(Indorsed in his own hand: "Scheme of new condenser for the iron cylinder, called the plate-condenser. It came to Soho, and many experiments were tried with it; but it came unsoldered, and the drum condenser was substituted.")

[15.] MR. WATT TO DR. ROEBUCK.

Glasgow, Feb. 19th, 1766.

* * * *

I intended to have seen you this week, but the

* *Anglicè*, tinman.

working barrel was not cast at Carron, which detained me. I have thought on a simpler circular steam-engine than what I mentioned to you, and which I expect will be practicable.

* * * *

[16.] MR. WATT TO DR. ROEBUCK.

Glasgow, Feb. 29, 1766.

* * * *

The piston-rod for the large machine is near finished. I am somewhat at a loss about sending it, as if sent on a common cart Mr. Singleton and the rest of your people will unavoidably see it, and it being hollow will occasion speculation. I believe it will be best to send it in a box.

I have set about making the circular engine, and I expect to have it done in about a week.

* * * *

[17.] MR. WATT TO DR. ROEBUCK.

Glasgow, April 20th, 1766.

I got home last night about ten o'clock. I called at Carron. Your cylinder is finished and sent to Carron wharf, with the ends on. I think you should send for it.

* * * *

[18.] MR. WATT TO DR. ROEBUCK.

Glasgow, May 14th, 1766.

The circular machine has taken a great deal more work than I imagined. It is not yet quite finished, but near it.

* * * *

[19.] DR. DARWIN TO MR. WATT.

Lichfield, 18 Aug. 1767.

* * * *

Now, my dear new friend, I first hope you are well and less hypochondriacal, and that Mrs. Watt and your child are well. The plan of your steam improvements I have religiously kept secret, but begin myself to see some difficulties in your execution which did not strike me when you were here. I have got another and another new hobby-horse since I saw you. I wish the Lord would send you to pass a week with me, and Mrs. Watt along with you;—a week, a month, a year! You promised to send me an instrument to draw landscapes with. If you ever move your place of residence for any long time from Glasgow, pray acquaint me. Adieu. Your friend,

E. DARWIN.

[20.] MR. WATT TO DR. LIND.

Glasgow, Jan. 5th, 1768.

"*Nil mihi rescribas, attamen ipse veni.*"

* * * *

I am going to be at home, God willing, for some time. I am going to try some things I am persuaded you will like to see (perpetual mobiles, the elixir magicum, and some other trifles of that kind). Seriously, it would give me great pleasure if you could spend a few weeks with me; I think I could entertain you. What I knew about the steam-

engine before you went away* was but a trifle to what I know now.

* * * *

[21.] DR. SMALL TO MR. WATT.

Birmingham, 7 Jan. 1768.

DEAR SIR,—Our friend Boulton will by this post send letters both to you and to Dr. R. I know not well how to resolve without seeing you. I have not the pleasure of being enough acquainted with Dr. R. to judge whether we should all suit

* To Madras and China, for which Dr. Lind had sailed in December, 1765. In the East Indies his health had failed, and a severe spitting of blood seems to have hastened his return home. During a short stay in Canton he took great pains to obtain information on the subject of Chinese arts and manufactures; and, after his return, he gained some fame in the mineralogical world, by having brought home specimens, both in crystals and pulverized, of the adamantine spar (as he calls it);—corundum, or corindon, as Klaproth and other later mineralogists have termed it. When, in 1789, this substance was examined and tried at Paris, at the request of M. F. de St. Fond, by M. Fontaine, one of the most skilful lapidaries there, he reported that the effect in cutting on the wheel, and drilling, was similar "to that which the powder of ruby, sapphire, or oriental topaz, might produce;"—a felicitous comparison, since all of those three gems are in point of fact transparent and beautiful varieties of corindon, the different names which they bear in commerce and jewellery varying with the different colours of the stone. The oriental topaz here spoken of—a comparatively rare and valuable species of gem—must not, however, be confounded with the topaz of Saxony, Scotland, Siberia, Australia, and Brazil; from which, independent of the difference in its chemical analysis, it is distinguished by possessing greater hardness and specific gravity, as well as a much more brilliant lustre. So the violet-coloured corindon is termed oriental amethyst, although widely different from the common amethyst, and greatly surpassing it in splendour as a gem. Previous to Dr. Lind's researches, the common corindon, although so well adapted to lapidary purposes, is believed to have been unknown in Europe.

one another. His integrity and generosity, everybody agrees, are great. You certainly know the proposal he has made to Boulton, who will tell you his determination about it. Before I knew your connection with Dr. R. my idea was, that you should settle here, and that Boulton and I should assist you as much as we could, which in any case we will most certainly do. I have no kind of doubt of your success, nor of your acquiring fortune, if you proceed upon a proper plan as to the manner of doing business, which if you do you will be sole possessor of the affair, even after your patent has expired. I had not thoroughly considered this part of the matter when you left me. In a partnership that I liked I should not hesitate to employ any sum of money I can command on your scheme, and I am certain it may be managed with only a moderate capital. Whether it would be possible to manage the wheel and reciprocating engines by separate partnerships without their interfering, I am not certain; if it is, Boulton and I would engage *with you* in either, *provided you will live here.* I am, in haste, dear Watt, your affectionate humble servant,

W. SMALL.

[22.] MR. WATT TO DR. ROEBUCK.

Glasgow, Jan. 28th, 1768.

I would have written you sooner, but have not yet got the little wheel completed. It was, as I suspected, a quantity of the putty that had got loose,

and, in the form of little balls, hindered the valves from shutting. On consideration I found that it would be very difficult to guard against that inconvenience if putty was used in the model; I therefore endeavoured to use some other substance, such as paper, cork, &c., that would remain where they were put; but from the complication of the grooves I could not make it tight in that way. I have therefore made some considerable alterations on it which will allow me to use sulphur for making it tight, and shall have a trial of it this night or to-morrow forenoon; meanwhile the other model is going on. * * (Indorsed in his own hand: "Our small wheel-engine; believe it was two semicircular grooves, about an inch diameter, in a wheel of 1 foot.")

[23.] MR. WATT TO DR. ROEBUCK.

Glasgow, April 15th, 1768.

I have been close working at the engine since I wrote you, but have not got it perfectly tight yet, though it is much better; the air seems to come in through some imperceptible pores in the metal. I am now getting an apparatus ready for setting it wholly in steam as before. Excepting this leaking I see nothing else to hinder its performance, as the vacuum is formed very suddenly, and is best at the beginning, when it would be worst if no air got in. The piston is very tight, and seems to last well. I would write you oftener, but my health is but indifferent and I have had

no good news lately, though I have every day expected to have had them to tell you. To-morrow the cylinder will be finished in the new way, and also made to act by steam above the piston. What the want is I will inform you next week. * *
(Indorsed : " Exp^{t} on a large model of the engine 7 or 8 inches diameter.")

[24.] DR. ROEBUCK TO MR. WATT.

Kinneil, 18th April, 1768.

I should have rejoiced to have received more favourable accounts of your trial ; but I hope in a few days you will have better success. I shall be glad however to give you the meeting at Kilsythe on Friday next, at twelve o'clock, to enter into a particular detail about it; and you will please to drop me a line if that day be convenient to you.

* * * *

[25.] MR. WATT TO DR. ROEBUCK.

Glasgow, April 19th, 1768.

* * * *

I had another trial this afternoon, which succeeded much better, the vacuum being quickly formed and no air. The mercury in the gauge-pipe rose to 24 inches, and will, I hope, rise higher when some things are altered : but we met with a sad misfortune : the mercury, by an unforeseen accident, found its way into the cylinder, and has played the devil with the solder. This throws us

back at least three days, and is very vexatious, especially as it has happened in spite of the precautions I had taken to prevent it. I would, with all my heart, wait upon you on Friday, but am far from being well, and the fatigue of the ride would disable me from doing any thing for three or four days; besides, I hope by that time to have a more successful trial, without which I cannot have peace in my mind to enjoy anything. Dear Sir, I hope you will excuse this—I do not know whether to call it mistake or blundering—but am certain that I had done all that I could, and hope that in the end good will come of it. Whether or not, I will do my duty to it. Farewell! (Indorsed: "Unsuccessful experiment with the large model.")

[26.] MR. WATT TO DR. ROEBUCK.

Glasgow, April 27th, 1768.

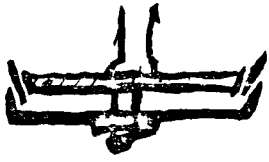
I got the damage done by the mercury pretty well repaired, and have tried the engine several times since. As the mercurial gauge-pipe cannot be used with safety, I estimate the vacuum by weights, applied to raise the piston of the condenser. This method is not quite so exact, but answers tolerably well. The condensing pump is 2 inches diameter. A weight of 47 pounds is *in equilibrio* with the pressure on it when the condenser has no communication with the cylinder; when that communication is open the vacuum is formed directly, and the condenser supports a weight of 42 lbs., which is coming as near the

whole pressure as we can reasonably expect. I will write more to-morrow. (Indorsed: "More successful experiment with the large model: degree of vacuum.")

[27.] MR. WATT TO DR. ROEBUCK.

Glasgow, April 29, 1768.

When the communication is first opened between the exhauster and the cylinder, the 42 lbs. [weight], that raises the piston of the exhauster, falls about 4 or 5 inches, and stops there. If that weight is then raised by hand, and left to itself, it does not descend again at all, but remains suspended. The reason appears to be, that a very minute quantity of air that entered with the steam was extruded by putting down the piston of the exhauster: the piston of the cylinder, that we feared most, is extremely tight, and may easily be made tighter still; it is made of pasteboard, baked with linseed oil, and put on like the leather of a pump-box. In order to get quit of that small quantity of air, I propose making two exhausting barrels instead of one, and giving them only half the stroke each that this has. I propose they should be worked by a double crank, the one ascending when the other descends, so that the pressure on the one that descends will nearly raise the one that ascends. Now, suppose the communication with the cylinder opened, and the piston of



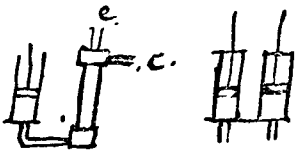
one of these raised, the steam will rush in and be condensed, and the greatest portion of the air will be in the condenser, because, being heaviest, it will go in with the first of the steam. Now, this piston, beginning to descend, shuts a valve that cuts off its communication with the cylinders; but the other piston ascending opens a fresh vacuum, in which there is no air, into which the remaining steam and air will go and be condensed, and the vacuum will be much more perfect than if there had been only one condenser having twice the stroke. If the vacuum is still not absolutely perfect, each of these cylinders may be made to take two strokes without any other loss than the friction of the exhausters, as they will balance one another nearly. Now, I think, two of the most important facts are settled,—the perfection of the vacuum and the suddenty of the condensation;—there still remains to determine the quantity of steam used. But before I do this I propose making the above improvement, and making the engine go of itself, that the strokes may be counted, and the water measured that is boiled away. These things are in hand, and will soon be done. (Indorsed: "Experiment with the large model; new condenser proposed." It is accompanied by a drawing of a double pump.)

[28.] MR. WATT TO DR. ROEBUCK.

Glasgow, May 10th, 1768.

I have got the two new exhausting cylinders cast, bored, and partly turned; also the new

condensers made; and expect to have it going again by the end of the week. The two cylinders stand side for side, the pipes at bottom, communicate with two condensers, which, by the pipe *c*, communicate with the large cylinder. There is a valve at *e* that prevents the air and water in the condenser from going into the big cylinder at the return of the piston of the exhauster, but obliges them to go out at the top of the condenser through the pipe *e*, having a valve at bottom to prevent their return. This pipe *e* has another use, viz., to measure accurately the quantity of water condensed each stroke, by observing what space it occupies in this tube. I take this to be the best way of determining that article, if we can make the pistons of the exhausters tight, so that none may be introduced that way. As soon as I have got it completed I will write you, that I may either come to you and give you account of the success, or you come here and see the machine go. I am uneasy till I know the exact quantity of steam consumed; though from several circumstances I think it will answer hopes. At any rate the vacuum is good and sudden; the consumption undoubtedly the least possible. (Indorsed: "Description of improved condenser.")



[29.] MR. WATT TO DR. ROEBUCK.

Glasgow, Monday. (Indorsed: "Seems to have been written in 1768, perhaps between the 10th and 24th May.")

I tried the engine on Friday and to-day; have not got it quite tight, but have the greatest reason to expect success when that is accomplished. The piston is very tight, and I see no alteration happen on the tallow employed there. There are several motions to adjust still. I shall have another trial and advise.

[30.] MR. WATT TO DR. ROEBUCK.

Glasgow, May 24th, 1768.

I received yours, and would have answered it sooner if I could have given you the satisfaction I now can. I this day had another trial of the engine with the double condenser: the vacuum was as before, 14 lbs. on the inch, and more readily formed, though this new apparatus is not perfectly air-tight. From some circumstances it was impossible to measure the water condensed in the way I proposed, but I found the engine could easily make twenty strokes per minute and snift properly, when the steam was middling strong. I filled the boiler to a certain mark, allowed it to come a-boil and boil one hour, in which time it wasted 300 cubic inches: I repeated this experiment with the same result nearly. Now 300, divided by 60, gives 5 inches in a minute, or $\frac{1}{4}$ inch each stroke. Now, the cylinder is $7\frac{1}{2}$ inch dia-

meter, squared is 56; deduct ¼ to give square inches: 42 multiplied by 12, the stroke, 504 cubic inches—about 3½-part of a cubic foot; but this used only the ¼ of an inch of steam. As we could not use all the steam, great part went off at the loading-valve, and some was needlessly expended from another cause, which I shall explain at meeting. Therefore, I speak within bounds when I say that every cubic foot of the contents of the cylinder will require only one cubic inch of water to be evaporated. I am even of opinion that, in a large engine, with a strong boiler and a hot steam, the half of that quantity will be sufficient. I intend to have the pleasure of seeing you at Kinneil on Saturday or Friday. I sincerely wish you joy of this successful result, and hope it will make you some return for the obligations I ever will remain under to you.

* * * *

[31.] PROFESSOR JARDINE TO MR. WATT.

Kinneil, Monday, 1768.

MY DEAR JAMES,—I have thought proper to drop you a few lines on the subject we canvassed to some length at Glasgow, which you will use as your own prudence shall direct, but consider as friendly hints from one who sincerely wishes you well.

The Doctor has been with you at Glasgow, and we have since had some occasional conversations. I waited to find, without direct inquiry, if he had

in any respect consented to the proposal from the South; but understand, that the more he is convinced of the practicability of the scheme, the keener he is of carrying it to practice yourselves for your mutual advantage; and I am perfectly convinced that though he may mistake particulars, it is one of his strongest motives that you may not only have the honour but the advantage of your own ingenuity. I found that he has this at present so strongly before him, that it would have been vain, and perhaps imprudent, for me to have suggested anything to the contrary. And, therefore, my opinion is, James, that you will find it necessary, on account of your intimate connection, to fall in with his sentiments, and contribute as speedily, and as vigorously as you can, to bring it to some conclusion. He has proposed to erect one immediately at Bo'ness. I know very well the objections you will have to this, and indeed to everything which will give you further trouble: but I apprehend when you consider deliberately the following particulars, you will endeavour to pluck up spirits for a few months longer. You are yourself perfectly satisfied as to the success you expect in practice, and I really apprehend that there is now so little to do for that purpose, that it is unnecessary to make any further division of your profit to a third person; for the very nature of your improvements is such that it is impossible it can fail to succeed much to your interest, even though it should not be carried to such perfection as might be expected from the gentleman in the

South's assistance. I know you will think the erection of one at Bo'ness a further trouble, but I am really of opinion that even that trouble will be productive of considerable advantages. It would be hard to be disappointed in any respect in the first attempt that you make, and it would surely be better that you should have not only a model, but a finished engine, either to proceed upon as a pattern or to dispose of, as may be convenient. Nor do I apprehend that your trouble will be so great as you are ready to imagine. You judge of it too much from what is past. You are now in a very different situation, and can begin at principles which you had formerly to labour at by experiment and calculation. The person who is your operator has surely now learned to take some of the trouble off your hand; and I flatter myself that it would be now nothing more than mere amusement to attend to the proportions and accuracy of the execution. The Dr. proposes, not only in the present but also in future undertakings, to have everything that requires great nicety and exactness, to be made by the best workmen, and, as far as possible, to follow the method of watchmakers, who have little more to do than to adjust and combine materials. This may indeed be not such a perfect scheme as to have the whole conducted in the same manner, but under particular inspection; but it may nevertheless do well, and at least ease you of a part of your trouble; and all improvements in this respect will occur to you much better afterwards. I wish

earnestly, therefore, that you would endeavour to keep away these plaguey headaches for a little longer. You have many motives, man, to have good spirits. You are surely very near to something that will be much to your advantage: the happiness, or at least the interest, of your family,—your own ease and amusement,—that life of ingenious indolence which you have often figured out to yourself, are all within prospect;—not to mention the honour of a discovery of so much importance, a circumstance which few would think so moderately of as yourself. I would, therefore, have you resolve immediately to spend a great part of the summer here. Mrs. Watt and her young son, I'm perfectly certain, will be most welcome guests—and I hope would not weary to spend some time here;—and, I trust, before you left us, you would find yourself considerably nearer the event of what has already been so long before you. My real and friendly advice is, that in your present circumstances (and even though not your own opinion), the above should be your resolution, and that no time should be lost, but as soon as possible to set about it. My compliments to Mrs. Watt.

Yours most sincerely,

GEO. JARDINE.

[32.] DR. SMALL TO MR. WATT.

12 Aug. 1768.

I am exceedingly glad to find that you are in London, and taking the steps necessary to secure proper advantage from your excellent invention.

Mr. Boulton had hopes of being in town about this time, but is prevented. A circumstance also has arisen very lately that will engage him to delay the execution of his steam-engine for some time. He, Dr. Darwin, and I will rejoice to see you, and to tell our neighbours the services you can do them. Mr. Edgeworth is a gentleman of fortune, young and mechanical, and indefatigable. He is not acquainted with Hately, but has taken a resolution of moving land and water carriages by steam, and has made considerable progress for the short space of time he has employed himself in that study. He knows nothing of your peculiar improvements, but seems to be in a fair way of knowing whatever can be known on such subjects. At present he is in Ireland. My respects, if you please, to Mr. Cumming. Get your patent and come to Birmingham, with as much time to spend there as you can. I am, with great affection, &c.

[33.] DR. SMALL TO MR. WATT.

Monday, I know not what day of September, 1768.

I did imagine you had fallen into some bottomless pit in Derbyshire, or had been dipped into a cistern of air compounded with the inflammable principle, so I am very glad to hear you are alive. Your very clever friend, Mr. Robison, and his pupil, passed Friday evening with me to my great satisfaction. I told them I hoped soon to travel in a fiery chariot of your invention. Dear Watt, I wish you a good journey, and am, with the

greatest regard, your most affectionate humble servant.

[34.] MR. WATT TO MR. BOULTON.

Glasgow, Oct. 20, 1768.

DEAR SIR,—I got safe home on Wednesday last week. When you were so kind as to express a desire to be concerned in my fire-engine, I was sorry I could not immediately make you an offer. The case is this:—By several unsuccessful projects and expensive experiments I had involved myself in a considerable debt before I had brought the theory of the fire-engine to its present state. About three years ago, a gentleman who was concerned with me died. As I had at that time conceived a very clear idea of my present improvements, and had even made some trial of them, though not so satisfactory as has been done since, Doctor Roebuck agreed to take my debts upon him, and to lay out whatever more money was necessary either for experiments or securing the invention; for which cause I made over to him two-thirds of the property of the invention. The debts and expenses are now about 1200*l.* I have been since that time employed in constructing several working fire-engines on the common principles, as well as in trying experiments to verify the theory. As the Doctor, from his engagements at Bo'ness, and other business, cannot pay much attention to the executive part of this, the greatest part of it must devolve on me, who am, from my

natural inactivity and want of health and resolution, incapable of it. It gave me great joy when you seemed to think so favourably of our scheme, as to wish to engage in it; I therefore made it my business, as soon as I got home, to wait on the Doctor and propose you as one I wished he would make an offer to, which he agreed to with a great deal of pleasure, and will write you in a few days, that if agreeable you may be a third part concerned, on paying the half of the cost and whatever you may think the risk he has run deserves, which last he leaves to yourself. If you should not choose to engage on these terms, we will make you an offer when the whole is more perfect, which I hope it will soon be.

The objections against the engine before the trials made last winter were, that it might be difficult to make a piston sufficiently steam-tight without water or some other fluid above it. Water cannot be used, because if any of it got in, it would boil and occasion a loss of heat. Oil of some kind was the next thought of; but possibly it might be destroyed in time by the heat. The next objection was, that the vacuum might not be formed by exhaustion sufficiently sudden or sufficiently perfect. On trial, tallow being employed to keep the piston tight, answered perfectly well, and did not appear to be changed in all the [trials] made; but on removing the tallow em[ployed] from above the piston, it was found to be [ ] so tight as to lose only four strokes in [ ] the want of it. In large engines this de[fect] would

be lessened in proportion as the squares of their [ ].

In answer to the second objection, the [vacuum] was formed sufficiently sudden, and very perfect, that is, within one-sixth part [of]. If this reciprocating engine should not [answer], it must be [from] some mechanical difficulty, which, I think, we may certainly get the better of. If Doctor Small should choose to be concerned with you in this, I have reason to think it would be agreeable to Doctor Roebuck, and would be highly so to me. If you should not choose to engage with this affair in its present state, or at any rate, you will let this letter remain a secret except to Doctor Small. I shall, at any rate, write you again soon, and am, dear Sir, yours,

JAMES WATT.

[35.] MR. WATT TO DR. LIND.

Glasgow, Oct. 25th, 1768.

* * * *

When at Birmingham, I spent a fortnight in the same house with your ingenious friend Captain Keir, who is a mighty chemist before the Lord, and a very agreeable man: he desired to be remembered to you. I am getting out my patent; but mum till it is finished. Shall be glad to hear of your cogitations, and if you can spare us a day or two this winter. Remember you lodge with me when you come; I have a great many things to talk with you about, as well as to hear much from you.

[36.] DR. ROEBUCK TO MR. WATT.

Bo'ness, October 30th, 1768.

* * * *

I shall be very glad to see you and Mrs. Watt soon at Kinneil. I want much effectually to try the machine at large. You are letting the most active part of your life insensibly glide away. A day, a moment, ought not to be lost. And you should not suffer your thoughts to be diverted by any other object, or even improvement of this, but only the speediest and most effectual manner of executing one of a proper size, according to your present ideas.

[37.] DR. ROEBUCK TO MR. WATT.

Nov. 9, 1768.

* * * *

I am every day expecting to see you and Mrs. Watt here, though I am as solicitous as yourself that every trial should be made of the small engine, which can be speedily executed, particularly the alteration of the condenser. But then I would not lose a single moment in completing what was resolved on. I am not so very desirous of hastening the patent; I am afraid we shall be called on to specify before it is our interest. I shall be glad to hear from you, by return of post, in answer to the above, and also whether you have sent your letter to Rotterdam.

* * * *

The above was forgotten to be sent last night,

since which time I have received yours of the 9th. You must bring your various attempts of the specification along with you; but we must not think of sending to London for some time. The whole plan of the larger engine must be fixed when you are here. Pray let me hear from you again in answer to the above.

[38.] MR. WATT TO DR. ROEBUCK.

Glasgow, Nov. 9th, 1768.

On considering the engine to be erected with you, I think the best place will be to erect a small house in the glen behind Kinneil; the burn will afford us plenty of cold water, and we will be more free from speculation than we can be about Bo'ness. I propose to suspend the lever so as to take a six-foot stroke in the pump for a four-foot in the cylinder; a pump of 18 inches square and 15 feet high will answer then, or a smaller for a greater height. I intend coming next week and concerting and giving the proper directions for chains, &c. I have written the specification two or three times over, but am not yet satisfied with it, though it is better than it was. (Indorsed: "Proposal for engine, to be erected at Kinneil.")

[39.] MR. WATT TO MR. BOULTON.

Glasgow, Dec. 12th, 1768.

* * * *

I have almost finished a most complete model of my reciprocating engine. When it is tried, I shall advise the success.

* * * *

[40.] DR. ROEBUCK TO MR. WATT.

Bo'ness, 22 Dec. 1768.

* * * *

I should be sorry to risk the property of the engine; wherefore by the first post write to your friend to take out the patent. I can spare the money without inconveniency. I shall be glad to hear from you, and more to see you.

[41.] MR. WATT TO DR. SMALL.

Glasgow, 28 Jan. 1769.

I wrote you last Sunday, with a copy of the intended specification, which I hope you have received. The plan I pursued in drawing it out, was in the first part to lay down my principles in as few words as possible, so as to be intelligible and clear from double meanings; so that they alone should ascertain my invention in so far as related to myself. This I have declared in the next sentence; but as I have been informed that some patents have been defeated because the specification was not clear enough to enable other people to execute the schemes, I have added descriptions of the machines, with drawings. However, if something after the nature of the first part could be contrived to answer the whole purpose, it would be better. The description of the wheel is very defective; but I have so few ideas at present, that it is with great pain I have been able to bring the whole the length you see.

I shall, therefore, be much obliged to you to sit in judgment upon it, and shorten it as much as you can to keep the meaning entire.

I have not heard from Boulton yet. I fancy it will be best to defer the bargaining till the Doctor and I be in England, which I expect will be this spring.

N.B. There is a section of the wheel and a plan of the other engine to be added to the drawing, when time allows.

I have been trying experiments on the reciprocating engine, and have made some alterations for the better and some for the worse, which latter must return to their former form. I have improved the condenser by reducing what was before a number of small pipes to one single pipe, surrounded at a little distance by another, and making cold water run between them. This both answers the end better and will considerably lessen the expense in great. I have misimproved the cylinder by making the bottom of cast-iron, which being obliged to be thicker than the brass or copper ones used before, does not communicate heat fast enough to evaporate the water left in the cylinder the first stroke, without being considerably cooled by it, and consequently condensing as much the next. I have also done wrong in removing the outer cylinder, which kept the inner one always surrounded by steam, ready to supply any loss of heat that might happen by evaporation from the inside surface. * * *

I have many things I would talk with you about,—much contrived, and little executed. How much would health and spirits be worth to me!

* * * *

[42.] DR. SMALL TO MR. WATT.

5 Feb. 1769.

Mr. Boulton and I have considered your paper, and think you should neither give drawings nor descriptions of any particular machinery (if such omissions would be allowed at the office), but specify in the clearest manner you can that you have discovered some principles, and thought of new applications of others, by means of both which, joined together, you intend to construct steam-engines of much greater powers, and applicable to a much greater number of useful purposes, than any which hitherto have been constructed; that to effect each particular purpose, you design to employ particular machinery, every species of which may be ranged in two classes: one class for producing reciprocal motions, and another for producing motions round axes.

As to your principles, we think they should be enunciated (to use a hard word) as generally as possible, to secure you as effectually against piracy as the nature of your invention will allow. You might declare in some such manner as the following:—

First, you intend that the vessels in which powers of steam will be employed to work such engines as you may construct, shall be heated,

before the working of the engines shall begin, at least as hot as the steam to be conveyed into the vessels, and that this heat of the vessels shall be rendered equable, whilst the engines work, by suffering them to be entered or touched in that time by no substance colder than the steam they are designed to receive, by covering them with materials which allow bodies so covered to cool very slowly, and by proper applications of heated bodies when they may be wanted. The vessels mentioned in this paragraph you call *steam-vessels.*

Secondly, in the engines which you may erect to be worked, either wholly or partially by condensation of steam, you intend that the steam shall be condensed in vessels distinct from the steam-vessels, though occasionally communicating with them. These vessels you call condensers; and, whilst the engine may be working, you intend to keep the condensers constantly at least as cold as the air then in the neighbourhood of the engines, by applications of water, and other means of cooling heated bodies.

Thirdly, whatever air or other uncondensible elastic vapour may impede the operations of the engines, you intend shall be drawn out by machines in the manner of pumps, to be worked by the engines themselves.

Fourthly, you intend that on different occasions the necessary steam shall be produced from different substances, solid or fluid, or partly solid and partly fluid, as may be most convenient; and also that the vessels in which the steam shall be

produced (which you call boilers), shall be of different forms on these different occasions.

Fifthly, in many cases you design to employ steam in producing reciprocal motions in a manner like to that in which portions of the atmosphere are now employed in ordinary reciprocating engines, to wit, by pressing at proper times upon pistons of proper structures.

Sixthly, to produce by means of steam motions round axes, you intend sometimes to employ reciprocatory joined to other machines, but more frequently steam-vessels of forms fitted to different purposes. These steam-vessels will be mounted on axes, and will contain weights, either solid or fluid, or partly solid and partly fluid; which weights, or the centres of their gravity, being constantly, whilst the engines work, pressed by steam beyond planes perpendicular to the horizon, and in which planes the axes will lie, will cause motions of the steam-vessels.

Seventhly, in these last-mentioned engines, in which steam-vessels must move round axes, on some occasions you intend to use the condensers described above; but on others, to discharge the steam from the steam-vessels, through proper outlets, into the atmosphere.

Lastly, to render pistons and other parts of the machinery air and steam-tight, instead of water you design to employ paper and pasteboard prepared with oils, oils themselves, or fat of animals, quicksilver, or melted metals.

February 7.—I have received your letter of the

28th January. Upon the whole, an Act of Parliament would be the thing; you obliging yourself to reveal to Commissioners, or to the Royal Society, every particular proper to be revealed. I am certain that, from such a specification as I have written, any skilful mechanic may make your engines, although it wants correction; and you are certainly not obliged to teach every blockhead in the nation to construct masterly engines. I wish we could anyhow meet before you specify. A matter of this kind cannot be managed by letters. I should have much to say to you about your machinery.

As to your invention for measuring distances, I know of nothing similar to it, excepting what I have formerly told you I had recommended in a case in which I was applied to as a mathematical man, and which is not so easy as yours, and another method I thought of for measuring the heights of mountains, which I never told you. I have invented little of late. An American friend of mine has discovered a method of making nitre monstrously cheap; but I do not know the method. He spent lately a week with me, but I did not care to know his secret before he had secured it. I am glad the alkali is attended to. I know nothing for which I would more willingly have quitted physic, if the invention had been mine.

Boulton has written to you. Come to live in England as soon as you can. Till then, do not fatigue yourself, and never think; and let Mrs. Watt nurse you mighty well. Do make my com-

pliments to her. Farewell. Captain Keir is in Berkshire. Mrs. Darwin has been long ill.

W. SMALL.

[43.] MR. BOULTON TO MR. WATT.

Soho, 7 Feb. 1769.

DEAR WATT,—By this time, I dare say, you have fully concluded that I am a very queer fellow, I having never answered your friendly letter of the 20th October, nor your last of the 12th December. In truth 'tis a shame, and I ask you ten thousand pardons. I could make many excuses, and tell you how much I have been engaged and hurried at London, Bath, Bristol, all over Derbyshire, &c., &c., with sundry other reasons, all of which I shall waive until I have the pleasure of seeing you at Soho.

I note what you say in respect to your connection with Dr. Roebuck, from whom I received a letter, dated the 12th December, offering me a share of his property in your engine, as far as respects the counties of Warwick, Stafford, and Derby. I am obliged to you and him for thinking of me as a partner in any degree; but the plan proposed to me is so very different from that which I had conceived at the time I talked with you upon that subject, that I cannot think it a proper one for me to meddle with, as I do not intend turning engineer. I was excited by two motives to offer you my assistance—which were, love of you, and love of a money-getting, inge-

nious project. I presumed that your engine would require money, very accurate workmanship, and extensive correspondence, to make it turn out to the best advantage; and that the best means of keeping up the reputation, and doing the invention justice, would be to keep the executive part out of the hands of the multitude of empirical engineers, who, from ignorance, want of experience, and want of necessary convenience, would be very liable to produce bad and inaccurate workmanship; all which deficiencies would affect the reputation of the invention. To remedy which, and to produce the most profit, my idea was to settle a manufactory near to my own, by the side of our canal, where I would erect all the conveniences necessary for the completion of engines, and from which manufactory we would serve all the world with engines of all sizes. By these means and your assistance we could engage and instruct some excellent workman, who (with more excellent tools than would be worth any man's while to procure for one single engine) could execute the invention 20 per cent. cheaper than it would be otherwise executed, and with as great a difference of accuracy as there is between the blacksmith and the mathematical-instrument-maker. It would not be worth my while to make for three counties only; but I find it very well worth my while to make for all the world.

What led me to drop the hint I did to you was the possessing an idea that you wanted a midwife to ease you of your burthen, and to introduce your

brat into the world, which I should not have thought of if I had known of your pre-engagement; but as I am determined never to embark in any trade that I have not the inspection of myself, and as my engagements here will not permit me to attend any business in Scotland, and as the Doctor's engagements in Scotland will not, I presume, permit his attendance here, and as I am almost saturated with undertakings, I think I must conclude to ———. No, you shall draw the conclusion: yet, nevertheless, let my conclusions be what they will, nothing will alter my inclinations for being concerned with you, or for rendering you all the service in my power; and although there seem to be some obstructions to our partnership in the engine trade, yet I live in hopes that you or I may hit upon some scheme or other that may associate us in this part of the world, which would render it still more agreeable to me than it is, by the acquisition of such a neighbour.

I am glad to hear that you have a model of your reciprocating engine in great forwardness, I being impatient to hear of its success. Query—is the wheel-engine invention also included in your transfer to the Doctor, or can it be separated from it with propriety? I hope it may not be long before you make this place in your way to London; and pray remember, when you come, always to put up at the *Hotel d'Amitié sur Handsworth Heath*, where you will always find a friendly reception from, dear sir, your affectionate humble servant,

MATTHEW BOULTON.

[44.] MR. WATT TO DR. ROEBUCK.

Glasgow, Feb. 10th, 1769.

Yesterday I received a letter from Mr. Enslie, with a particular account of the lake near Rotterdam, which, as soon as I have studied a little, I will transmit to you; but, from what I have seen, it will not be a proper place for us, as the greatest part of the expense appears to be surrounding it with a dyke, and making a proper outlet into the river. The value of the ground is less, and the number of acres greater, than we were calculating, and the quantity of water raised by the water-mills immense.

Mr. Jardine would tell you better than I can write you what he saw of the engine. I am now making the outer case to it, and a thinner bottom, without which they will not answer so well, heat being too long in penetrating cast-iron. I have now set it up in a most convenient place, where the experiments can be made to your satisfaction. Its doing twice as well as the common, is, I think, absolutely certain, from what Mr. Jardine saw; and there is little reason to fear but what it will do all we expected. My headaches have not been so violent as usual this week, and, I hope, are abating. * * *

(Indorsed: "Drainage in Holland; cast-iron model does well.")

[45.] MR. WATT TO DR. ROEBUCK.

Glasgow, 11 Feb. 1769.

* * * *

I wrote you last night of my having taken

asunder the engine to add an external cylinder and a thinner bottom; for at first, when the cylinder is cold, there is a small quantity of water left in the cylinder. Immediately on producing the vacuum this water is converted into steam, and thereby cools the cylinder considerably: now, if there is an external cylinder, and the bottom of the internal one is thin, the steam on the outside will warm it again instantly, and no steam will be condensed the next time—(this was the case in the last model). However, I thought it was necessary to try if this external cylinder could be wanted, by introducing steam between the bottom of the cylinder and a false bottom below it. I also made this bottom cast-iron, that it might in every respect resemble a large one. In the first place, I found that the sides of the cylinder, being exposed to the open air, lost a great deal of heat; and that the cast-iron top condensed much steam, which lay on the piston and was troublesome. I found, in the next place, that the heat could not sufficiently suddenly pervade the cast-iron bottom, and that there was a quantity of steam condensed by it. These things will be remedied by making the top and external cylinder of wood, and making the bottom of the internal of copper, which transmits heat very fast. Both the coppersmith and cooper are at work on it, and it will be done with all expedition, but I am afraid not so soon as Wednesday; at least I cannot be sure that it will be in a condition to work then. I therefore beg you to delay your coming till I write you of my

having tried it again. I send enclosed Mr. Enslie's letter, which is distinct enough. I shall be obliged to you to bring it with you when you come, that we may consider it together. * * * (Indorsed: "Experiment with model with cast-iron cylinder.")

[46.] MR. HANDLEY TO MR. WATT.

London, 18 Feb. 1769.

SIR,—I expected to have had the pleasure of seeing you in London before now. This informs you that your patent is completed, all but the specification, which you must give. The time limited is four calendar months from the date of the patent, and which bears date the 5th day of January last. You will be prepared when I see you to give the full and proper description; and you must use great caution therein, lest any other person, who may see your specification, should endeavour at an improvement on your plan.

Your most obedient servant,

THOS. HANDLEY.

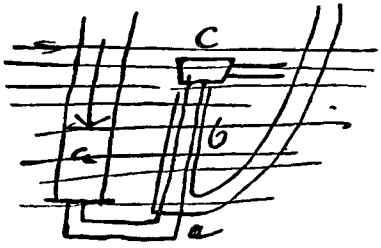
P.S.—You may begin to use your method as soon as you please, and need not wait to give the specification.

[47.] MR. WATT TO DR. SMALL.

Glasgow, Feb. 22d, 1769.

I received your draft of the specification, with which I am much pleased. I have, however, ven-

tured to make some small alterations, which I shall send you a copy of when revised. I made an imperfect trial to-day of an alteration in the condenser, with which I am much pleased; it is this:—in the piston of the condenser there are valves as in a common pump; it is 2 inches diameter, stroke 6 inches; contains 18 cubic inches water. The pipe *b* of the condenser is surrounded with an outer pipe; cold water runs between. The pipe *b* and box *c* contain above 9 cubic inches water; at *c* is a sliding valve which is opened, and kept open for a little space when the piston *a* is at the lowest. The mouth of the pump being above water, the piston, when it was at top, threw out almost all the water contained above it; when it is at the bottom, the water in the cistern runs in at the valve *c* and fills the pump up to the level of the water in the cistern, and by that means puts out the water heated in the last stroke; when the piston is raised the valve is shut, and the steam, or what of it is not condensed, pushes the water before it into the pump, and endeavours to follow it into the pump, but is condensed with a crack. It is not possible, if the water be cold, that any of it can survive this operation; and the machine is simple and works easy. I propose working the condenser by a waterwheel. I have found my engine much better of the alterations I men-



tioned in my last. Still plagued with headaches, and sometimes heartaches. I received Mr. Boulton's, to whom compliments.

[48.] MR. WATT TO DR. ROEBUCK.

Glasgow, 14 March, 1769.

I this day made trial of the power of the engine, and found that, after it was clear of air, it readily lifted 620 lbs., and, I believe, would have lifted more, but had none at hand. The whole pressure on the piston is about 740 lbs.; this was with a steam not able to support above one, or at most two inches of mercury. It will not be, I think, possible in any model to know exactly the quantity of steam used, because the outer cylinder, &c., have so many joinings that we cannot make sure of them all. I shall be glad to know when you can be here by return of post. (Indorsed: "Experiment with cast-iron model: seems to have been 8 inches diameter.")

[49.] MR. WATT TO DR. ROEBUCK.

Glasgow, March 16th, 1769.

Since I wrote you I added 80 lbs. to the load of the engine, making in all 704 lbs. net, which it lifted easily. However, the additional weight being a large mortar and inconvenient, I took it off and wrought it a few strokes with the 624 lbs., which it raises on half a revolution of the handle of the condenser, or the stroke of our pump. This seems to depend wholly on the coolness and quan-

tity of water that passes through the condenser, which I have an easy method of increasing. I find this cylinder, being of cast-iron, and near one-eighth inch wider at one end than it is at the other, is not so steam-tight without oil as the block-tin one I had last was; I therefore make use of the oil pump and train-oil, which answers perfectly well, keeping a constant circulation. The best and cheapest cylinders will be of block-tin; they will be defended from external injuries by the wooden case, and have nothing to fear from the inside. I shall be glad to see you, but Thursday and Saturday next are our Sacrament days, so would wish you to come before or after them, as we cannot decently try any experiment on them. (Indorsed: "Experiment on cast-iron model.")

[50.] MR. WATT TO DR. SMALL.

Glasgow, March, 1769.

Below is a copy of a draught of the specification, altered from yours in some places, for the following reasons:—The specification is delivered on oath, and declared to be a true description of the invention. 2ndly. There is no occasion to make the previous heating of the cylinder an article, as that is common to all engines. 3rdly. I thought it best to be explicit as to the methods of keeping the cylinder warm, as they will be obvious to every person who sees one of the engines. I have done the same in the fourth and fifth articles, being willing that nobody may be able to entertain a

doubt of the meaning of the specification. I omitted altogether the article of boilers; as, if the rest of the patent stand good, that article can be of no use to any other person. I have, however, added another article merely by way of prevention, as indeed the whole of what is said about the circular-machine is with that view, as the first articles effectually secure it.

[Here follows a draught of the specification, not materially different from that which was finally adopted for enrolment.]

I made a trial of my engine with the new condenser. The whole pressure of the atmosphere on the piston is 742 lbs. I applied an actual weight of 704 lbs., which it lifted easily without much assistance from the pressure of steam. Some of the things it was loaded with being clumsy, I took off 80 lbs. for conveniency, and wrought many strokes. It raised the 624 lbs. by one stroke of each pump of the condenser (or each stroke of the engine), and if I had had cold water in greater plenty, would have done with less. I made use of train-oil to make the piston tight, and a kind of Savery's engine, which I described to you under the name of the oil-pump, which returned the oil constantly to the piston. I don't find it necessary to take off the water condensed in heating the cylinder, as it soon evaporates in working. There is little or no water condensed between the cylinders. The inner cylinder will be best made of block-tin, because it is not liable to be dissolved by oil. It can be made very equally wide by

flattening a sheet of it and making it equally broad, and then turning it up and soldering. It does not wear the pistons, nor seem to be worn by them itself; secondly, when worn out it will not lose much of the value of the metal, of which it need not con[tain much], as it need not exceed a quarter of an inch in thickness.

[51.] MR. WATT TO DR. SMALL.

Glasgow, April, 1769.

* * * *

I have still improved the condenser. I have rendered its pumps frictionless; I have, therefore, increased its size. I have reduced it to the last simplicity, that is, to have no parts but the pumps, and a great valve that admits the water, also frictionless, though air-tight. The pumps have an inch of stroke, and are five inches diameter; half a cubic foot of cold water can pass through them during one stroke, if necessary.

* * * *

[52.] DR. SMALL TO MR. WATT.

Birmingham, 18 April, 1769.

I received your letter yesterday, at one o'clock. I have heard nothing from our friend Cumming, and was, therefore, obliged to send your specification to your attorney last night, much as you sent it to me; for in hopes of seeing yourself or hearing from him, or both, I had not lately studied it with the necessary attention. I thought there was no

time to send it to Cumming, but desired your attorney to advise with him, and to make all possible haste. I hope you intend to be at Berwick to meet his despatch, that you may save some little time. Your attorney will receive my letter to-morrow, 19th April. He cannot, probably, send you the engrossed specification in less than four days. The post to Glasgow is six, I believe. You, therefore, receive the epistle on the 29th; and then six days remain. Thou art a philosopher, Watt! I approve the additions in your yesterday's letter. A linen-draper at London, one Moore, has taken out a patent for moving wheel-carriages by steam. This comes of thy delays. I dare say he has heard of your inventions. Do come to England with all possible speed. At this moment how I could scold you for negligence! However, if you will come hither soon, I will be very civil, and buy a steam-chaise of you and not of Moore. And yet it vexes me abominably to see a man of your superior genius neglect to avail himself properly of his great talents. These short fevers will do you good. I shall always be, with great affection, &c.

I admire your last condenser much.

[53.] MR. WATT TO DR. ROEBUCK.

Glasgow, April 28th, 1769.

I have to-day made drawings of the regulator and new condenser, and set them to work. I have found the cause of the condensation during the ascent of the piston; it is owing to this valve not

being immersed in steam, for to-day I stopped the neck of the steam-pipe where it enters the cylinder, so that the steam could not go into the cylinder. On exhausting the condenser and opening and shutting the regulator, the mercury sunk as much in the gauge-pipe as though it had got into the cylinder; the bottom of the regulator grew sensibly cold during the time of exhaustion, and was warmed again by the steam. I am happy I have found out this. I draw the pit-head frame to-morrow. By letter from Dr. Small, I am informed that one Moore, a linen-draper, has taken out a patent for drawing chaises, &c., by steam. This was a thing I hoped to accomplish by the circular engine. His specification must be examined. You know Hately knew some little about the circular engine, though not about the principles on which it must be constructed. Possibly he may have some hand in this. * * (Indorsed: "Experiment on cast-iron model; finds out that the regulator condensed steam by lodging water.")

[54.] MR. WATT TO DR. SMALL.

Glasgow, 28 April, 1769.

* * * *

If linen-draper Moore does not use my engine to drive his chaises, he can't drive them by steam. If he does, I will stop them. I suppose by the rapidity of his progress and puffing, he is too volatile to be dangerous. Let me know all you know of him.

Nothing less than the experience I have had of steam and steam-engines will enable anybody to erect one of my engines so as to be perfect, unless they should see one of mine and copy it exactly. On trying what quantity of steam was used by the model, I found that when wrought by the force of steam only, it took fourteen strokes in the minute; but when the condenser was used, it took only seven or six. On looking on the gauge-pipe that shows strength of steam, I saw it fell as much in the going up of the piston as in the descent. How could this happen? The bottom of the cylinder was thin copper; it was immersed in steam; heat must penetrate it quickly. I was puzzled. The regulating valve was not immersed in steam; there was a cavity in it could hold a small quantity of steam; could this cause it? It did. I stop the neck of the steam-pipe, where it enters the cylinder. I exhausted the condenser, and wrought the regulators backwards and forwards; the steam sank in the gauge-pipe as much each stroke as if it had got into the cylinder, which it could not. On applying the finger to the lower side of the regulator, it was hotter and colder by turns, as you filled or exhausted it. Great mischief may arise from small causes. I intended, even before I detected this, to immerse the regulator in steam; but now I will put the oil-pump in also. I have improved the regulator, rendered it less, and more simple,—rectangular, and easy of execution. I have begun to erect an engine of an 18-inch cylinder and 5-foot stroke, at Kinneil, the Doctor's

place. However, it is to be done as privately as we can, as we do not propose to puff; therefore we expect your silence on this head.

You want a steam-chaise; pray make one. I give you leave, and will also give you advice,—not gratis, however, but for good deeds done and to be done. Seriously, you will oblige me if you will negotiate the following affair: I find that if the engine succeeds, my whole time will be taken up in planning and erecting the reciprocating engines, and the circulator must stand still, unless I do what I have done too often, neglect certainty for hope. Now Mr. Boulton wants one or more for his own use. If he will make a model of it, of 20 inches diameter, at least, I will give him my advice and as much assistance as I can. He shall have liberty to erect one of any size for his own use, and if he should choose more, the terms will be easy, and I shall consider myself as much obliged to him. If it should answer, and he should not think himself repaid for his trouble by the use of it, he shall make and use until he is paid. If this is agreeable to him, let me know, and I will propose it to the Doctor, and doubt not of his consent. I wish Mr. Boulton and you had entered into some negotiation with the Doctor about coming in [as] partners. I am afraid it is now too late; for the nearer it approaches to certainty, he* grows the more tenacious of it. For my part, I still think as I did, that it would be for our mutual advantage. His expectations are solely from the reciprocator;

* Dr. Roebuck.

possibly he may be tempted to part with the half of the circulator to you. This I say of myself. Mr. Boulton asked if the circulator was contrived since our agreement; it was, but it is a part of the scheme, and virtually included in it. * *

I am resolved, unless those things I have brought to some perfection reward me for the time and money I have lost on them, if I can resist it, to invent no more. Indeed, I am not near so capable as I was once. I find that I am not the same person I was four years ago, when I invented the fire-engine, and foresaw, even before I made a model, almost every circumstance that has since occurred. I was at that time spurred on by the alluring hope of placing myself above want, without being obliged to have much dealing with mankind, to whom I have always been a dupe. The necessary experience in great was wanting; in acquiring it I have met with many disappointments. I must have sunk under the burthen of them if I had not been supported by the friendship of Dr. Roebuck.

* * I have now brought the engine near a conclusion, yet I am not in idea nearer that rest I wish for than I was four years ago. However, I am resolved to do all I can to carry on this business, and if it does not thrive with me, I will lay aside the burthen I cannot carry.

Of all things in life, there is nothing more foolish than inventing. Here I work five or more years contriving an engine, and Mr. Moore hears of it, is more *éveillé*, gets three patents at once, publishes himself in the newspapers, hires 2000 men, sets

them to work for the whole world in St. George's Fields, gets a fortune at once, and prosecutes me for using my own invention! * * You talk to me about coming to England just as if I was an Indian that had nothing to remove but my person. Why do we encumber ourselves with anything else? I can't see you before July, at soonest, unless you come here.

* * * *

[55.] MR. WATT TO DR. ROEBUCK.

Glasgow, May 1st, 1769.

I send enclosed plan and elevation of the engine.* I think the two supporters of the great beam should be 14 inches square, at least; those of the spring beams of the size commonly used when of that length. The two main supporters must be about 14 inches asunder at the top, to admit of the iron straps that secure the axis. You ask what is the principal hindrance in erecting engines; it is always the smith-work. I would wish the boiler bottom to go on first. I will soon be East, and give directions about the man-hole and top; meanwhile I wish you would set the chain-makers to work. You know we purposed to make it a three-ply chain (of the best tough iron, that breaks with a dusty surface); the middle link ¾ inch thick, the two side ones ½ inch each, the breadth about 3 inches. I wish the wood of the frame to be got ready, but not to be put up till I come. The

* The plan and elevation referred to do not now accompany the letter.

pattern of the regulator is at the founder's, and part of the condenser is made for the little engine (the model I mean). I am busy drawing and planning the several parts; was hindered on Saturday by a head-ache, or would have sent this. The supporters will not need to be much sunk into the ground, but must be kept upright by shores, and be mortised with cross bearers at bottom. I shall to-morrow give directions about sheeting the tin for the cylinder, and getting the bottom made. (Indorsed: "Directions about engine, to be built at Kinneil.")

[56.] DR. SMALL TO MR. WATT.

16 May, 1769.

I am exceedingly glad you were in time, though it was to the disgrace of my calculation. After much inquiry about Moore, I can learn nothing satisfactory, only that he is no profound philosopher, and so, in all probability, unacquainted with the properties of substances of which you have availed yourself. Perhaps he may pay you a large sum of money for leave to use your inventions. If so, ask 12,000*l.* and not 1200*l.* He is rich and sanguine; and indeed, if wheel-carriages and vessels can be moved commodiously by steam, the invention is worth much more money. Your success with the model delights me. I have been applied to for one of your reciprocating engines by Mr. Parrot, for his brother, a coal-owner. What will you build him one for, equal to a 40-inch common one?

I have had several conversations with Mr. B. about your proposals. We pay no regard to those reports to which you allude in relation to Dr. R.; but we think it impossible to settle any partnership without meeting, our ideas of cultivating the invention appearing to be different. We have sufficient confidence in the wheel-engine to undertake it; but if it succeeds, either it will supersede the other, and so injure the proprietors of *it*, or it will be superseded by the other. We should not like to have either of these happen, and think both ought to be prosecuted in conjunction as a manufacture; not in single machines, which an engineer must travel to superintend the erecting of. To render this practicable, we have thought of several expedients; but all of them require the acting partners to live near one another, and a fixed plan to be pursued, not to be departed from but by common consent.

Both Mr. B. and I would willingly assist you in making models of the circulator; but we are not fond of instructing workmen here just at present. I repeat that we do not think the two schemes separable to your advantage, or Dr. R.'s, and that we are clear it is possible to serve the whole world with steam-engines, for all sorts of purposes, without stirring from home or employing any vast capital. I have only time to add that I am, with great affection, &c.

Suppose you talk to Dr. R. on the subject of this letter.

[57.] DR. ROEBUCK TO MR. WATT.

Bo'ness, May 19, 1769.

* * * *

Mr. Hately left this place to-day: I have closed all accounts with him. * * I hear that he has already sent for a copy of your specification, and that he charges me with revealing his secrets to you. I am very glad, however, that he cannot charge me with revealing your secrets to himself. I shall be glad to hear what progress you make, and when I am to expect you at Kinneil. * *

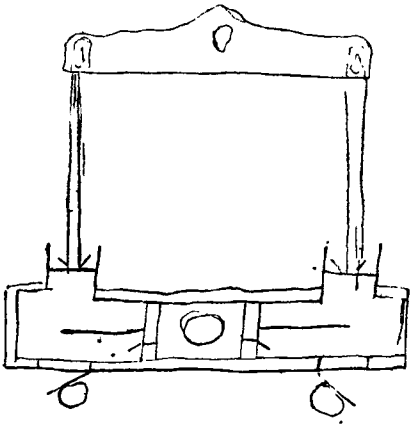
[58.] MR. WATT TO DR. SMALL.

Glasgow, May 28th, 1769.

Yours of ——— is with me, and I am informed from London that the specification is enrolled in due time, and from Bo'ness that Hately has sent for a copy of it, for which I hope he will not be much wiser. I observe what you say about the circulator and reciprocating engines not being separable, which I shall let rest till I meet you, only must observe that for many uses I do not think anything can supersede the reciprocator, or for others the circular; and to these uses, in case of their being in any degree separate property, they must be confined: but I also agree that they should go hand in hand. * * *

I have this day made a conclusive trial of my new condenser; the frictionless pump afforded a lodgment for air, and was therefore rejected, and

block-tin cylinders put in its place. These cylinders are 3½-inch diameter; the piston moves up and down 1¼ inch; the piston stalks are suspended on a beam on edges; the beam is made to vibrate by



means of two spiral wheels that press down first one end and then the other. This spiral puts them down very quick in the first part of its motion, but during the last fourth of its revolution it only moves them 1¼ inch, that being the only time that anything beside friction opposes its motion, as it is then putting out its water and raising the whole power of the air on the other piston. During this part of the revolution, the valve at bottom is opened by a trigger, having little to oppose it, as that lobe of the condenser is then a plenum; then the water surrounding the condenser being higher by six inches than the top of the pumps, rushes up through the condenser and pump, and cools it. On trial, the condensation is more rapid than ever, the force necessary to move the condenser much less than

you could well imagine, and the ease of execution quadruple what it ever was of any former condenser, for instance. This one is made of wood and block-tin. I am considerably advanced with the 18-inch engine, and expect to have it going in a month, that is, provided no unforeseen mischief happens to oppose us; for I am pretty well satisfied in my own mind that I have provided remedies for all the faults I know of, the only thing doubtful being what will happen to the oil. If it is destroyed too fast, I must endeavour to find some way of making the pistons tight without it. I mentioned to you a method of still doubling the effect of the steam, and that tolerably easy, by using the power of steam rushing into a vacuum, at present lost. This would do a little more than double the effect, but it would too much enlarge the vessels to use it all; it is peculiarly applicable to wheel-engines, and may supply the want of a condenser where force of steam is only used; for, open one of the steam-valves, and admit steam until one-fourth of the distance between it and the next valve is filled with steam; shut the valve, the steam will continue to expand, and to press round the wheel with a diminishing power ending in one-fourth of its first exertion. The sum of this series you will find greater than one-half, though only one-fourth steam was used. The power will, indeed, be unequal, but this can be remedied by a fly, or several other ways. These circular engines must be luted with steam as well as the reciprocators. * *

I have just now got a curious book, being an

account of all the machines, furnaces, methods of working, profits, &c., of the mines of the Upper Hartz. It is unluckily in German, which I understand little of, but am improving in by the help of a truly chemical Swiss dyer, who is come here to dye standing red on linen and cotton, in which he is successful. He is, according to the custom of philosophers, *ennuyé* to a great degree, but seems to be more modest than is usual with them; and, what is still more unusual, is attached only to his dyeing, though he has a tolerable knowledge of the rest of chemistry. He promises to make me a coat that will not wet, though boiled in water. This would be of great use to a hundred people I see just now running by, wet to the skin, no doubt cursing God in their hearts; I verily believe the drops are an inch diameter. To return to the book: it contains an account of all the unsuccessful experiments that have been tried in the Hartz, and I assure you it gives me some consolation to see the great Leibnitz, the rival of Newton, bungling repeatedly, applying windmills to raise ore while water ran idle past him. There is, among other machines, the fellow of Blakey's, only wrought by water, and a full and true account why it did not succeed, which *he* should read. Their machines in general display great ingenuity, and ignorance of principles. I enclose you some of Chaillet's red yarn, boiled in soap, and some as it is dyed. As to Mr. Parrot's engine, cannot give you a positive answer. Our idea at present is first to supply those places where coals are 20*s.* per ton and

upwards, that is, provided the experiment in great answers.

[59.] MR. WATT TO DR. SMALL.

Glasgow, 5 July, 1769.

I have none of yours lately. This comes to inform you that Dr. Roebuck set out for England yesterday or to-day, and will probably be at Birmingham before he returns. I have never spoken to him on our subject since I informed you, nor can I with propriety do it at present, but leave it to Mr. Boulton and you to do in it what you see proper. But I would not wish that at any rate the negotiation should be entirely broken off until I have the pleasure of seeing you, which will be soon after this machine is finished; that is to say, if I am successful, as I hope to be. I have got almost every part of the machine ready for putting together, the boiler set, the great beam hung, &c., and may possibly in three weeks complete it. * * I forgot to tell you that the condenser of the large machine is finished, and is much to my liking; the two pumps of it are tin, 9-inch diameter, and the rest of it hardened lead, fastened to a strong frame of wood.

* * * *

[60.] DR. SMALL TO MR. WATT.

26 July, 1769.

Dr. Roebuck was so obliging as to call upon me both in his way to London and in his return. On

the first of these occasions I was out, and on the second he was in haste, so that we had no conversation; but he had a good deal with Mr. Boulton about the steam-engine. * * Dr. R. will tell you what passed between himself and Mr. B. about the engines. I have no kind of doubt of your success in that you are now building, and much approve the alterations described in your two last letters. I cannot imagine that much oil can be destroyed, especially if your oil is fresh and animal. I long to see you here, and yet Dr. R. said you would not be in England this summer. * * Of all things, I least understand the *art de teindre*, so that I know not what to say of your Swiss philosopher. The machine you describe as Blakey's is a very old invention, and has been ascribed to Archimedes, though I believe it was used before he lived. I once considered its advantages and disadvantages, but have forgot them. * * Steam coming into a vacuum in small portions would do more than you suppose, but is encumbered with great difficulties, no doubt. * * Whatever happens, come into England. Captain Keir, Boulton, Dr. and Mrs. Darwin, all often speak of you with the greatest regard; and I am, with the utmost esteem and affection, &c.

[61.] MR. WATT TO DR. SMALL.

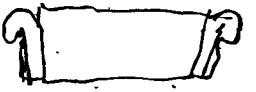
Glasgow, Sept. 20th, 1769.

You were long in answering my last letter, and I think I have almost repaid you in kind. I would

have written you sooner, but was tired always telling what I was to do, and wanted to be able to say I had done somewhat. I had also the standing excuse of bad health, which had received a considerable addition from a tooth-ache, which employed a very large share of my attention both by night and day for three months, and was often the cause of severe headaches. After many fruitless trials of both external and internal medicines, I believe it was cured by the continued application of sach. sat. poultice; however, cured it was, but not before it had demolished the best of my few grinders. Since that left me, I have been in better health than you could expect a valetudinary projector to be in, whose anxiety for his approaching doom keeps him from his night's sleep, and whose fears at least equal his hopes.

I have no doubt but you would readily have excused this preamble, and would be glad to know somewhat of the health of the engine, as well as of the projector. Well, then, the trial has not been decisive; but I am still allowed to flatter myself with hopes. You shall judge. The pump is 18½ inches diameter and 25 feet high; the cylinder 18 inches wanting $\frac{1}{8}$, or $17\frac{7}{8}$; the boiler 5½ feet at the bottom, which is the widest part; the cylinder is then loaded with nearly 12 lbs. on the inch, for the area is 253·8 cubic inches the load, 46·1 cubic feet, or, at 62 lbs. per foot, 2858·2 lbs. The adjusting and fitting all the parts together took longer time than we thought of; but after much close labour we got it brought to a trial about a fortnight ago.

After the air was pumped out, the piston of the cylinder descended about two feet, and stopped there, being willing to come no further. Steam was admitted, and it ascended; on a second trial, it came down only a few inches. From some circumstances, I thought the bucket of the pump was in fault; the water being let off and the bucket drawn (which was not easily done), the leather was found to be what we call *flyped*, or turned inside out, thus:—



On examining the piston of the cylinder, the pasteboard used for leather there was found torn. It was conjectured that the jack-head hole might not be in the centre of the cylinder; that was endeavoured to be rectified, and three-ply of pasteboard was put on the piston instead of one. A double leather was put on the bucket, and the two were pinned together. We again set to work. After the air was pumped out, the piston descended briskly for a few strokes but grew gradually slower as the water rose in the pump. When the water came to the pump-head, the piston always waited some time after the valve was open to condensation before it descended. On suffering the strength of steam to increase, the piston descended more briskly, but I thought hardly in proportion to the increased pressure on it. The bucket of the pump made a groaning noise, by which I thought the friction in it might be more than usual, it having been rusty a little when put up. After some strokes the piston failed, and the oil came through the condenser. The piston being

drawn, cork was put on in the same manner as the pasteboard; the oil-pump was examined, and the passage through which it should discharge its oil found too small. This we could not remedy at Kinneil. On putting in the cork piston, in descending it did not apply itself to the cylinder at one place of one side; on examination, the cylinder was oval in that place, either from some inaccuracy in the making or from some injury received in setting it up. This also we could not immediately remedy. We drew the bucket and drove nails into the leather, both to smooth the barrel and presently diminish the friction. I thought the cork piston, when warm and pressed by the steam, might apply itself to the cylinder, notwithstanding the inequality; on trial it did so, but failed after a few strokes; the pump had more friction than ever, because both the leather and nails were too much thickness on the bucket at once. I took out the nails and cut the leather short; I put in a piston of cork flatwise, so that it was pressed against the cylinder only by its own elasticity, and not by the steam. The engine wrought rather quicker than before, but raised little water, as most of it got down by the side of the bucket, now too slack; the piston did not fail in this experiment, and if the oil-pump had in any measure done its office, would have answered; but as it was, a considerable quantity of steam got past it, which was heard constantly rushing into the condenser. The leather of the bucket was lengthened, the piston was changed for two-ply of pasteboard, sewed together;

the pump threw good water, the engine went as well as ever, but always waited a little at top before it descended; the rushing of steam was heard as usual, and in this as well as in the former experiments, some oil came through with the steam and mixed with the water, which it made milky and would not easily separate, but ran away with it. The oil in the cylinder and on the piston was grown thick, ropy, and white, and was heavier than common oil. The oil's coming through the condenser is thus accounted for: the oil-pump being incapable of returning it, part of it lay at the bottom of the cylinder, where any water that was in it at first would also lie under the oil; when the valve was opened to vacuum, this water would boil violently, and carry some of the oil along with it; in the succeeding strokes this could not happen, but the oil-pump always returning some oil, though not enough to drown the piston, the steam hurrying through would drive it to dust, and bring it through the condenser along with it. From some experiments I made since, I hope that some means may be fallen upon to render oil on the whole less miscible with water; the calx of lead dissolved in it seems to answer that purpose in some measure, but had the oil been returned as intended, it would have been out of harm's way. I wish, however, you would consider this subject, and try some experiments, as it is of great consequence that the oil should endure some time, or the use of it must be forbidden. The pasteboard used for the piston appeared not to be so thoroughly soaked in the

linseed oil as what I had formerly used, which, with the piston's not being exactly fitted to the cylinder, and consequently leaving too great a space for the pasteboard to cover, appears to have been the cause of its destruction. I am now preparing some better, and am going to try several other things. As to the condenser, I laid aside the spiral wheels for making noise and thumping, and substituted a crank; in other respects it performed well enough, and seemed to condense the steam readily. It was driven by a man, our water-wheel not being properly adjusted, from some circumstances too tedious to write. I am inclined to try my former condenser again, having thought of some improvements on it; however, that I do not think material, as either of them will do.

I have hitherto spoken only of the circumstances that are against me; I must say something of what is for me.

The boiler with a small fire easily supplied more steam than we could destroy, although there were many outlets for it, which we took no care to stop, being employed otherwise. The boiler-top and wooden cylinder were very tight, as were all our vacuum joints and valves; the plates that let out steam were at the man-hole door and at the screws that fastened the steam-box to the wooden cylinder, which, had other things been right, we should soon have corrected. The only conclusion I can draw from this trial, is, that supposing we cannot employ oil to keep the piston tight, and that we cannot make it better than we had it, it would work easily

with 8 lbs. on the inch, and would not consume above half the steam used by a common engine. Even this I will not positively affirm, although I think there is reason to believe it.

I am now employed in making the following alterations: enlarging the descending valve of the oil-pump to three inches square (above nine times its late size), making a new piston of cast-iron (the last having been wood), to fit the cylinder within a sixteenth all round; the cylinder is to be made exactly round and straight where it stands; making a new condenser with two pumps, to each of which belong eight pipes, eighteen inches long, three-fourths diameter, with cold water running about them; the pumps 4¾-inch diameter and 4-inch stroke. I am also just now employed in taking a survey of the River Clyde, to serve some purpose of improving the navigation on it. This I would not have meddled with had I been certain of being able to bring the engine to bear; but I cannot, on an uncertainty, refuse every piece of business that offers. I have refused some common fire-engines, because they must have taken my attention so up as to hinder my going on with my own. However, if I cannot make it answer soon, I shall certainly undertake the next that offers; for I cannot afford to trifle away my whole life, which God knows may not be long. Not that I think myself a proper hand for keeping men to their duty; but I must use my endeavour to make myself square with the world, if I can, though I much fear I never shall.

Dr. Roebuck was to set off for England as to-day. I have had some conversation with him about making Mr. Boulton and you a proper offer, which I expect he will do when with you. From what I now write you, in which I assure you I have not concealed any circumstance that makes against the engine, you will judge how far it may be your interest to engage in it on its own account. As to the Doctor, he has been to me a most sincere generous friend, and is a truly worthy man. As for myself, I shall say nothing, but that if you three can agree among yourselves, you may appoint me what share you please, and shall find me willing to do my best to advance the good of the whole; or, if this should not succeed, to do any other thing I can to make you all amends, only reserving to myself the liberty of grumbling when I am in an ill-humour.

I began this letter a week ago, but wanted life to finish sooner. You will excuse its length, and, if you can, answer it in course of post. My compliments to Mr. and Mrs. Boulton, Dr. and Mrs. Darwin, Captain Keir, &c.

I am, dear Sir, yours,

JAMES WATT.

I forgot to observe that I am not sure that the boiler was sufficiently purged of air when we began our experiment. From the circumstance of air always coming at the condenser, I suspect now that it was not; and our experiments never lasted long enough to clear it. I observed also that the piston

always descended quickest when near the bottom, which I imputed to the cylinder being more round at that place.

I have calculated friction, *vis inertiæ*, &c., at 700 lbs.; the power of the engine, including the pressure of steam, at 4200, which exceeds the work to be done by one-sixth. At this rate the cylinder always is supplied by leaks of the piston with as much steam as can run through the steam-valve into the condenser with our $\frac{1}{6}$ atmospheric-pressure. The size of the steam-valve is six square inches; the pipes to and from it wider.—Sept. 25th, 1769.

[62.] MR. WATT TO DR. ROEBUCK.

Glasgow, Sept. 24th, 1769.

Doctor Black only told me to-day of your going off as this day, or I should have wrote you sooner. I got only two days' surveying before I was drove home by the rainy weather, which has also somewhat hurt my health. I tried an experiment to-day that gives me hopes that oil may be rendered less mixible with water, by dissolving a small quantity of lead in it. If this answers, which I shall know to-morrow, there is no fear of us. I am preparing the new piston, oil-pump, and condenser.

When you are at Birmingham I expect you will try what can be done with Mr. Boulton, and hope you will be able to conclude some bargain which, even though it should appear a little hard for us, I would wish you to accept, from the fol-

lowing considerations:—1st. From Mr. Boulton's own character as an ingenious, honest, and rich man. You know him much better than I do, but the worst I have ever heard of him amounted to his being a projector. 2ndly. From the difficulty and expense there would be of procuring accurate and honest workmen, and providing them in proper utensils, and getting a proper overseer or overseers. If, to avoid this inconvenience, you were to contract for the work to be done by a master-workman, you must give up a great share of the profit. 3rdly. The success of the engine is yet far from being verified. If Mr. Boulton takes his chance of success from the account I shall write Dr. Small, and pays you any adequate share of the money laid out, it lessens your risk, and in a greater proportion than I think it will lessen your profits. 4thly. The assistance of Mr. Boulton's and Dr. Small's ingenuity (if the latter engage in it) in improving and perfecting the machine may be very considerable, and may enable us to get the better of difficulties that might otherwise damn it. Lastly. Consider my uncertain health, my irresolute and inactive disposition, my inability to bargain and struggle for my own with mankind; all which disqualify me for any great undertaking. On our side, consider the first outlay and interest; the patent; the present engine, about 200*l.* (though there would not be much loss in making it into a common engine); two years of my time, and the expense of models. (Indorsed: "Advises to apply to Mr. Boulton.")

[63.] DR. SMALL TO MR. WATT.

10 Oct. 1769.

I had your letter three days ago, and have held several conversations with our friend Dr. Roebuck about the scheme. He goes to London to-morrow, to stay one week, and in that time Boulton and I shall determine whether we can accept the offer he has been so obliging as to make us. Unluckily we have both just engaged in another scheme, which will very speedily require all the ready money we can at present spare, and I have a vast aversion to borrowing, although I would sooner borrow on this occasion than on any other I know, both because the engine must succeed, and because it is your affair. * * *

Your detail about the engine I have considered very carefully, and am in no degree discouraged. Your cylinder is not accurately made, and I suspect its materials to be capable of compression, so as to press the piston. The quantity of oil lost must be trifling after your oil-pump is of due size, if there is a groove in the bottom of the cylinder to receive it, and to convey it to the pump. If you will put flour in your oil, that will stop all crevices, and not wear your piston or cylinder. Do you not leather your water-pump too much? As to the condenser, I should prefer that which will preserve your distilled water, and the little oil that must always come with it. This conveyed into the boiler will hurt it less than other water, and your oil will accumulate there, and I suppose no way lessen your steam.

Boulton and I will do anything we can do to have you here, and to forward your success. Dr. R.'s proposal is perfectly agreeable to us; only as to me it is unfortunately made after the engagement of very near all my money. You shall hear from us again in less than a fortnight. In the mean time favour me with a few lines. All your friends here think of you with the highest esteem.

[64.] MR. WATT TO DR. SMALL.

Glasgow, Oct. 21st, 1769.

I am really sorry on my own account that your engagements hinder you from entering into our scheme; for that ought to be the result of your deliberation. Though there are few things I have wished more for than being connected with you, on many accounts, yet I should be very loth to purchase that pleasure at expense of your quiet, which might be the case if you involved yourself in more business than you could easily manage, or, what is worse, find money for. Besides, this is not a trade, but a project. No man should risk more money on a project than he can afford to lose. I must, however, beg the favour of writing to you as though you were concerned. I am obliged to you for the thought of collecting the oil in the boiler; the distilled water I thought of before. Your flour I have tried long ago; it disposes the oil to mix with water and sink in it. A balsam of sulphur has been recommended to me; I shall try it when I get things in order. I do

not imagine the compression could hurt much, for it must have caused the piston to make marks in the cylinder, which I do not remember to be the case, though I think it well worth examination. The cylinder was a full quarter inch thick and 18-inch diameter. At the worst place the long diameter exceeded the short about $\frac{3}{8}$; it was made of the best tin, not hammered. If the engine succeeds, I propose making them of copper. Now, would the difference of pressure on the sides and ends of the oval be any otherwise than as the difference of their diameters? for that it did not gripe the piston all round I am certain. I have thought of a method of making the cylinder true, and hardening it a little without taking it down, by hammering it with a mallet on a piece of hard wood fitted to it. Consider of any other thing that could hinder the cylinder from exerting its full power, and advise; think also of substances to do for pistons without oil.

* * * *

[65.] MR. J. ROEBUCK, JUN., TO MR. WATT.

2 Nov. 1769.

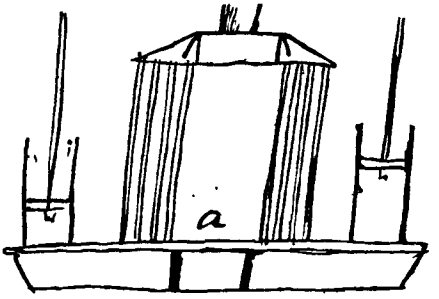
When I left you I fully expected to meet my father near at home, but, contrary to my expectations, I found a letter from him from Birmingham, that he did not know when he should set out, as some very particular business had occurred to detain him. He says that Boulton has accepted of a share in the engine.

[66.] MR. WATT TO DR. SMALL.

Glasgow, Nov. 3rd, 1769.

I wrote you about a fortnight ago, and have been impatient to hear from you; for, though from what I said before I would scarcely, if it were left to myself, advise you to engage in this scheme, yet I am selfish enough to wish you would do it of your own accord. I have been so busy surveying, that I have not yet got the proposed alterations completed, though they are in great forwardness.

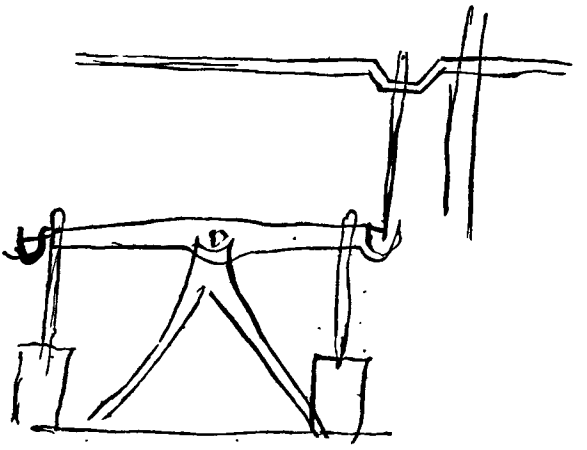
The new condenser consists of two sets of pipes, eight in each set, thus:— $\begin{matrix} 0\,0\,0\,0 & 0\,0\,0\,0 \\ 0\,0\,0\,0 & 0\,0\,0\,0 \end{matrix}$: they are each $\frac{3}{4}$ inch diameter and 18 inches long, 16 inches of which will be evacuated each stroke of the pump; they are to be $\frac{1}{2}$ an inch distant from one another in all directions; each set is to be surrounded at $\frac{1}{2}$ an inch distant in a box of wood, through which cold water can be made to run at pleasure. They are joined at top by a thin cast-



iron box, through which they communicate with

the steam. It is made sloping at the ends, that as little useless water as possible may be in circulation. They are joined at bottom by another cast-iron box, through which they communicate with the pumps, which are of copper, 5 inches diameter; two diaphragms of wood prevent their communicating with one another, the box being continued only for strength. It was indeed originally made with an intention to have no communication at top, but the steam to enter at *a*, by which means the valves needed only be water-tight, whereas they must be air-tight above; but on condensation the steam, whenever it entered (which would be as soon as any part of the pipes was empty), would rise, or attempt to rise, through the water in the pipes, and would heat it; but the piston of the pump still ascending, that water would descend into the box below, and part might get into the pump, and be there converted into steam; not being exposed to much condensation at best, if it got no further than the box it would remain warm until the cold of the pipes made a vacuum, when it would boil and go to them to be condensed, and it is much to be feared that this heating and cooling might prolong the time of condensation. I have sometimes thought that something of this kind happened in the other condenser, and concurred with other devils to plague me; and indeed I was so out of humour with myself and it, I did not try all experiments I might have done to clear that up. I make use of the same beam and crank I had before, only I place

these pumps at the extremities of the beam, where they have about four inches stroke. The way the



crank is applied I think simple, yet answers as well as a crank can answer.

[67.] DR. SMALL TO MR. WATT.

5 Nov. 1769.

Nothing will give me more pleasure than to contribute in any degree to your prosperity, whether I can become an associate with you or not. Although I hate debts, yet on this occasion I have ventured to propose borrowing money from the only persons to whom I would be obliged in that manner. Should it suit them to accommodate me, I will accept Dr. R.'s offer immediately, as will our friend Boulton. If a metal is in any degree flexible, and is formed into an elliptical cylinder, and the outside of that cylinder is everywhere

pressed by a fluid, it must change its figure. This I will demonstrate, if you require demonstration. As to marks from the piston, these, I should suppose, would be scarcely visible if the whole ellipsis was regularly changed into another figure not much different from itself, but yet capable of griping your piston. So I conclude that if the cylinder is of flexible metal it ought to be exactly circular, besides being incapable of compression in the manner I mentioned before. Since I last saw you I have made, and seen made, some hundreds of experiments on mixtures of metals, and can recommend several for your cylinder, and an infallible method of rendering it truly circular; but I do not choose to trust to the post what may be of use to you by remaining secret. I wish you would try the bag-piston we have formerly talked of, which resembles bellows, but is better, because it can be distended at pleasure by heightening the column of the distending fluid, and because its friction may be diminished at pleasure by lessening its contacting surface. I see no reason, my friend, why it should not be perfectly tight, and, if so, why you should not condense at both ends of your cylinder, and drive all before you, back-stroke and fore-stroke. I scarce hope to find any substance that will prove perfectly tight, and yet easy to be moved without oil. The contents of the bag should be oil. Perhaps charcoal dust may prove a better addition to your oil than flour, which ought indeed from theory to do just what you have found it to do. Though I had not

thought of that, I have thought of a very easy method of constructing your wheel, and of a most easy and obvious method of moving carriages by a reciprocating engine, provided a tolerably tight piston can be found. The weight of a machine for a post-chaise will not be more than 300 lbs., water and all, and it will be contained in very small compass. I am afraid this is so easy the Frenchman may have discovered it.

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[68.] TO DR. SMALL AND MR. BOULTON.

Birmingham, Nov. 28, 1769.

GENTLEMEN,—Whereas Mr. James Watt has assigned to me two-thirds of the property of the patent of the steam-engine, which he took out some time in the course of the last winter, I hereby offer you one-half of the above two-thirds, or one-third of the whole patent, on condition that you pay to me such a sum, not less than one thousand pounds, as you, after the experiments of the engine shall be completed, shall think just and reasonable; and twelve months from this date you are to take your final resolution. I also oblige myself to procure Mr. Watt's assent to this agreement.

I am, Gentlemen, your obedient servant,

JOHN ROEBUCK.

[69.] DR. SMALL TO MR. WATT.

Birmingham, 30 Nov. 1769.

I have time only to say that Mr. Boulton and I have agreed with Dr. Roebuck.

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[70.] MR. WATT TO DR. SMALL.

Glasgow, 12 Dec. 1769.

I received yours, and shake hands with you and Mr. Boulton on our connection, which, I hope, will prove agreeable to us all. I have just got the new alterations of the engine ready to carry to Kinneil, where I should have been with them long ago had I not somehow or other got into the good graces of our present magistracy, who have employed me in engineering for them, (as Mr. Smeaton terms it;) among other things I have projected a canal to bring coals to the town;—for though coal is everywhere hereabout in plenty, and the very town stands upon it, yet measures have been taken by industrious people to monopolize it and raise its price 50 per cent. within these ten years. Now this canal is nine miles long, goes to a country full of level free coals of good quality, in the hands of many proprietors, who sell them at present at 6*d.* per cart of 7 cwt. at the pit. There is a valley from Glasgow to the place, but it has a rise of 266 feet perpendicular above our river; I therefore set that aside, and have found among the hills a passage, whereby a canal may come within a mile of the town without locks, from whence the coals can be brought on a waggon-way. This canal will cost 10,000*l.*—is proposed 16 feet wide at bottom, the boats 9 feet wide and 50 feet long, to draw 2½ feet water. I have also contrived a method whereby vessels can be brought into the dry dock at Port-Glasgow, though they draw much more

water than the common rise of the tide, by means of a lock.

[71.] DR. SMALL TO MR. WATT.

26 Dec. 1769.

Although your operations on this canal may a little retard your progress in steam-engines, I rejoice in every opportunity which can serve to publish your ability and integrity. I wish with all your attention you may be able to succeed perfectly in this engine for Dr. R. without a new cylinder. But I am not very anxious about reciprocating engines since I have considered more carefully the circulating; one of which, equal to four horses, I can get made for fifteen guineas or less. Dr. R. is still in London. Pray let us lose as little time as possible after his return to you, for fourteen years will soon be gone. * *

I will insure you against Hately for one-thousandth per cent.

* * * *

[72.] MR. WATT TO DR. SMALL.

Glasgow, 3 Jan. 1770.

Yours received. I would not have meddled in Glasgow business had I thought of so tedious a job. It has been rendered more so by monstrous weather, which would have hindered the engine at any rate; neither did I want totally to cast away the scabbard when I drew the sword. Nobody knows of my connection with you and Dr. R., nor do I want them to know it till it appears we are all in the right. Vanity also bade me tell Glasgow

people they might be served as well at home as by strangers. The time has not been thrown away, for the *vaguing** about the country, and bodily fatigue, have given me health and spirits beyond what I commonly enjoy at this dreary season, *though they would still thole amends.* Hire yourself to somebody for a ploughman; it will cure ennui. However, I believe the satisfaction I have in your bearing a part of my burthen has done as much as anything. I give myself little pain about the cylinder; I should even be pleased to be convinced the fault lay there. I suspect another thing in the condenser:—at first setting out, all is full of water:—now, that water will be heated by the steam and forced by it into the pump, where it will be cooled, but some water will still remain in the middle part, which cannot come out nor be cooled but by boiling. This may take some time, as the heat the metal had acquired will be transmitted to it gradually: all this will be greatly remedied in the new condenser.

I am glad to hear of your 15*l.* worth; I hope you intend trying it directly. I admire Huyghens' level, but nothing that can vibrate will answer. Levelling can be done more correct than you imagine: I levelled eleven miles repeatedly within three or four inches. Refractions have been blamed for errors of instruments. * * *
I have long ago considered saving of water to locks—all schemes too gimcrack, and not much worth while.

* "*Vagor* expeditus."—Hor.

[73.] DR. ROEBUCK TO MR. WATT.

Kinneil, Jan. 17, 1770.

I arrived here well last night, and shall be glad to see you here as soon as possible. But pray do not let it be longer than next Sunday; the sooner you come, the better, that the further trial may be executed of the engine. I have much to say to you of Dr. Small, &c.: I very much esteem the Doctor.

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[74.] DR. SMALL TO MR. WATT.

Birmingham, 23 Jan. 1770.

Some weeks ago I had bespoke a large piece of hat to be made of cotton, in hopes it might be rendered steam-tight, and I intended to have sent it to Dr. Roebuck and you, but the hat-maker, after trying all the methods he has thought of, cannot make it. He says cotton cannot be made into hat. I delayed to answer your letter till I should know the fate of this enterprise. A carpenter is making a pattern for the caster of the 15*l.* wheel. I am glad you are easy about cylinders, for I am perfectly so about condensers. * * Whether it is that I grow old, or that my health lessens, I know not; but both my invention and my industry decay vilely. I have not thought of anything new for several months, and am monstrously dull. I have forgot what you said about the space occupied by a cubic inch of water converted into steam of different heats, and so cannot well calcu-

late about the wheel. I am against the solid weight, because, if it should be used, the wheel and valves must be executed with more accuracy and expense.

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[75.] MR. WATT TO DR. SMALL.

Glasgow, Jan. 31st, 1770.

Cotton was proposed by my friend Chaillet, when I was questioning about proper substances for pistons, and I once thought of trying it, but was deterred first by its price, and secondly by the very thing you have found, that it could not be easily made to cohere without glue or weaving. The substances I have hopes of are pasteboard, cork, tow, and horse-dung mixed; I propose to separate the gall and sand from the dung by washing. I have found by experiment that for making joints steam-tight there is nothing equal to it, as it is of no consequence whether the joint is naturally good or not, if you employ it. Where the joints are tolerable, and cleanliness is necessary, pasteboard is the best, and for ground joints thick soft paper. As to the solid weight, if you don't regard a little mercury, it needs not have any accuracy that would be difficult to give. I am afraid that Newton's metal will calcine, and I would with the solid piston use pure mercury. The true composition of Newton's metal is equal parts tin, lead, bismuth, $\frac{1}{9}$ mercury. Remember to make your steam-pipes so that none of the mer-

cury may go out at them. Cubic inch water becomes cubic foot vapour: greatest effect at heat of 224°. * * As to want of contrivance, I have felt severely the very thing you complain of; it was about its height when I saw you last: it is rather better, but I really think that on the whole I grow less inventive as I grow older, but I have the consolation that what I do contrive generally answers better. To-day I entered into the thirty-fifth year of my life, and I think I have hardly done thirty-five pence worth of good in the world; but I cannot help it. I do as much as indolence and *ennui* permit, and I think myself less indolent than I once was. There has been a mist all day to-day; *ennui* seized me soon after I went out, and several things increased it, so that I have had enough ado to keep from telling you my vexations; but I know by experience that one's own are much too many, and that the best thing one can do is to think on something else if one can. I go to Kinneil on Monday or Tuesday; compliments to Mr. Boulton, &c.

[76.] DR. ROEBUCK TO MR. BOULTON.

Bowness, Feb. 7, 1770.

DEAR SIR,—You and Dr. Small will be somewhat surprised that I have not written to you; and you will not be the less so now that you hear from me, when I tell you that a single step has not been advanced towards the engine since my last letter. The fact is Mr. Watt hath been con-

stantly and necessarily engaged in planning the Glasgow canal. But in three days I expect him here, and he has promised not to leave this place till the whole of the alternate engine has been effectually tried.

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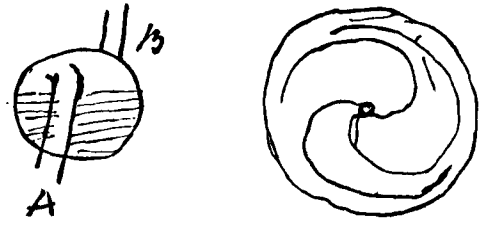
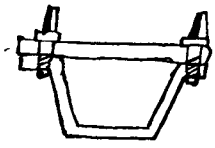
[77.] MR. WATT TO DR. SMALL.

Feb. 25th, 1770.

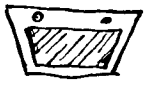
Now for the exclusion of solid pistons. Before I saw you last I had made a model of wood, nine inch diameter, of the very construction you are now about. I brought it so far a length as to move with blowing into the steam-pipe; but, on applying the steam, some putty it was tightened with got loose, and spoiled my valves. Bad health, some other difficulties, and the prosecution of the reciprocator prevented the bringing to conclusion. It was to have no condenser; the first method of preventing the mercury from coming out was by making the steam-pipe a spiral; if it got into these spirals it would be emptied again; and even supposing some small quantity to travel towards the condenser, it might be caught in a ball placed on the spiral pipe near the valve thus:—*A* leads to the condenser, *B* to the wheel; the experiment was



made so bunglingly that I have not given myself the trouble of remembering if any mercury got out at the regulator or not; but I think not. However, I see that I altered the model, and took away the spirals, which were only grooves in the wood; but I believe that was only to get it more easily made tight. The objection to this machine is the steam required to fill each steam-pipe, which is lost; and in the other way, with a valve to each pipe, the piston metal can be effectually hindered from entering the steam-pipes. If you can stop Newton's metal from calcining, I agree it is the easiest and best way for small engines. I am still of opinion that the wheel will move fast. Now, since I have gone so far, let me suggest a method of making your wheel and valves tight. Let the valve frame be made easy for the groove, and about half inch thick; put a ply of pasteboard



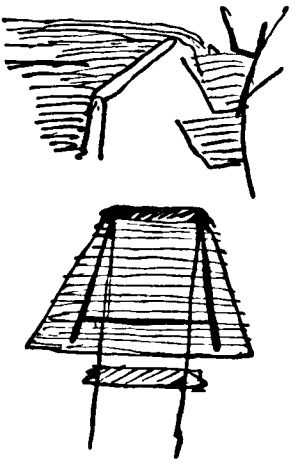
Section of groove.



Valve-frame.

below the frame, and the same up each side, and place it in the groove in its proper place; then lay a ring of pasteboard all round each side of the groove within the screws, and slip over each valve frame, taking care no pasteboard project over the frames or grooves; then screw all fast; if the metal is half inch thick your screws may be three inches asunder. The substance for these valves is

broad-cloth soaked with strong linseed oil or the shoe varnish for which I gave you the recipe, and dried in a stove of 140°, though if as hot as 200°, no matter (care must be taken it does not become too hard); when dry, paint one side with white lead and oil, having first made it smooth: dry that and pumice it, and it will become like ass' skin; this smooth side applies to the frame. The valve itself must be made of iron plate, thin enough to yield, if not exactly flat. It must have two small pivots to hang by, as it must not be trusted to the cloth; it is fastened to the cloth by a smaller plate, little enough not to touch the frame when the valve shuts, and screwed together by three screws; the valves must be shut by a spring. I have been at Kinneil, and I have made the cylinder round, but being obliged to come away before everything was ready for trial, go there again on [Saturday] or Sunday. Meanwhile, my people [are busy] preparing. I have had two mechanical [experiments] succeed with me lately; the one was a [mill] wheel on a three feet fall, where the tail [stream] rises three feet occasionally; yet I have constructed the niche so that it goes [well] and with as much power at those times as at any other. The wheel is six feet diameter, and six feet



long, and has a very curious sluice for giving it water, so that scarce any of the power is lost by head-water, or at least the least possible. By inclining the upper board more or less you can give more or less water, or stop it by raising it perpendicular. The other successful experiment was preventing the wind from blowing down a chimney, by a machine a-top with two valves, which, when one was shut, opened the other. For my comfort I am told this is an old contrivance: however, I never saw it before, and it has been effectual. Farewell.

Along the margin of this letter is written, in Mr. Watt's hand, "Dionysius Papinus contrived surrounding the boiler, top and bottom, with fire; see his *Ars nova aquæ efficacissime elevandæ ope ignis.*"

[78.] DR. SMALL TO MR. WATT.

Birmingham, 28 Feb. 1770.

I have nothing to say about the engine, excepting that the pattern will go to Colebrook-dell tomorrow.

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[79.] MR. WATT TO DR. SMALL.

Kinneil, 10 March, 1770.

I received yours of the 26th, which I could not positively answer sooner for the following reasons. A trial made of the engine had given great hopes of its being nearly complete. A trial of the new condenser was wanted to be made, as upon that

the possibility of my getting it left depended. That trial was made yesterday, and had not the hoped success, which, with other things I shall mention, will prevent me from obeying your summons.

On my coming here from Glasgow I made the cylinder round in the way I proposed, and tried it with the old condenser and a piston of baked pasteboard. There was no oil on the piston. The engine came down much faster than ever she had done in the former trials, but always rested a little before she began to move. I wrought her with this piston for an hour or two: it was considerably worn by the motion, and seemed not to be thoroughly baked. I took it out and put in a cork piston, which swelling and becoming very tight, I was obliged to add a cwt. to the outside to move it; this made two cwt. on the outside, besides the bucket, which is heavier than the piston, but hardly sinks itself. The cork piston also wrought without oil; however, I put on the oil pump and wrought it some time. With that no oil comes through the condenser after the first or second stroke; and I think even that may be prevented, though at the same time I do not see any material odds in the going of the engine when it has or when it wants oil. I wrought this piston for several hours, and think it has rather become better than worse. There are therefore two essential points ascertained, a true cylinder, and a piston tight without oil, and seemingly durable. So far well. The condenser seemed to despatch

the steam instantly, for moving it faster or slower neither accelerated nor retarded the engine; yet the engine does not commence its motion so soon as the condenser opens, but waits two or three seconds, then advances with a considerably accelerated motion to the bottom. This fault undoubtedly lies in the middle part of the condenser retaining heat, which it gives out by degrees to the water lying on it; for our cylinder draws no air. The engine at slowest made six strokes a minute, and might be considerably assisted by hanging the beam altogether below the axis, instead of having it in the centre of gravity, as at present. I was considerably elated at the success of this trial, and impatient to see the success of the pipe condenser, which has as much depressed me: for, instead of making six strokes a minute, I could hardly persuade it to come in at all, which I attribute to the retention of heat by a piece of cast metal that joins the two sets of pipes; though this was made as thin as possible, yet it seems to be the *remora*. The pipe condensers I had in the models were made of white-iron, but it is not easy to make one of this size sufficiently thin without risking it being crushed. Copper is, to be sure, the proper substance, but the difficulty of getting its joints tight persuaded me to make it of iron, which has rendered it useless. I am going to try more experiments on it to-morrow, and if I cannot persuade it to perform better, must return to the old condenser, which, I think, I can greatly improve. N. B. The consumption of steam is as moderate as

expected. I will write you soon the further success, and send the scheme of new condenser, if necessary. You cannot conceive how mortified I am with this disappointment. It is a damned thing for a man to have his all hanging by a single string. If I had wherewithal to pay the loss, I don't think I should so much fear a failure, but I cannot bear the thought of other people becoming losers by my schemes, and I have the happy disposition of always painting the worst.

Now, things being in this situation, I cannot think of leaving it without some greater satisfaction. Some time ago I was employed by the trustees for the Annexed Estates to make a survey of a canal from Perth to Cupar of Angus. This I promised to execute this month, or beginning of next. I also engaged for some surveys of lesser canals; all these are consistent with my attention to this engine, for, after I have planned any [new] alteration, I have a person I can trust to execute [it in my] absence, which I take care not to be too long. [Besides], on the 27th of May I must also remove my dwelling [from] one part of Glasgow to another, and as I have an [immense] quantity of one sort of moveables and another, I cannot [devolve] this business wholly on Mrs. Watt. I find, on calculating [days], that I must either drop the engine experiments [or the trip] to Strathmore or Birmingham: though I should drop [the former] I cannot expect to have the engine finished time en[ough], at least I cannot be certain that I shall, before I should [have] to set out for you; and it

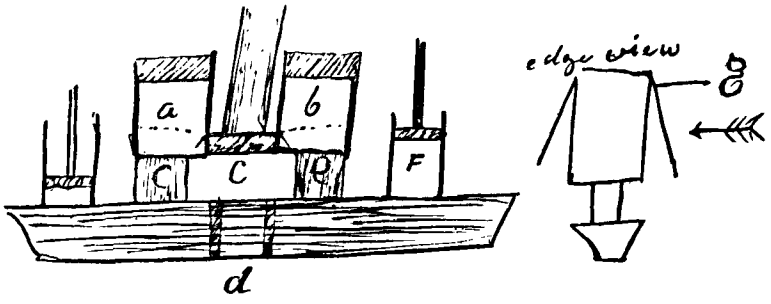
would be with a heavy heart if I came to you with doubts about it. I have consulted with the Doctor, and the result is, that my and your interest is, that everything should yield to the engine, and that I must refuse your invitation, though I regret my not being able to accept of it on many accounts. I still propose being with you in June, when I hope to show you more fully the propriety of this refusal. I was obliged for the same reasons to refuse going to London with the Bill for the Monkland Canal. Give Dr. Roebuck's and my compliments to Mr. Boulton, Captain Keir, &c.

[80.] MR. WATT TO DR. SMALL.

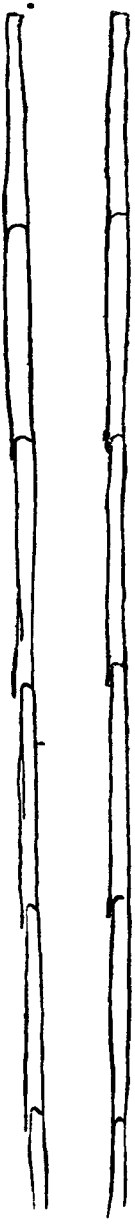
March 16th, 1770.

I wrote you from Kinneil much in the dumps after an unsuccessful experiment on Monday. I again tried the pipe condensers, with no better success than before; I then made a small hole to spout into the space between the two valves, and immediately obtained a condensation about as speedy as with the former condenser. I opened another larger hole, as it was easy to find that the first could not admit the water fast enough; the second could not admit it in a proper direction, and we found some difficulty to get it out as fast as it came in. I was therefore obliged to remain contented with thinking I have discovered the *remora*, which appears to be what I wrote you.

The improved condenser:—



The copper pumps, 5-inch diameter, and bottom communication of the last remain; two pieces of wood at *d* prevent any direct communication between the two pumps. *e e* are square pipes, whereby the pumps communicate with the cooling-boxes *a b*. These boxes are nine inches high, five inches thick, and six inches broad; they are made of hammered iron. Six inches high of these boxes is left uncovered, so as to have an opening six inches square quite through them; the greatest part of the top is also open; all these openings are shut by valves opening outwards, made of sheet iron, and covered with bend-leather, i.e. pump-leather. The part *c*, which joins the two boxes to the steam-pipe, is made of thin copper, and is as short as may be. There are two pierced diaphragms in the direction of the pricked lines, and inclining a little upwards. The operation is:—on drawing up one of the pistons, the water in the box *b* by its gravity descends, and, there being vacuum in the steam-pipe, there will also be vacuum in its upper part; the regulator being opened to condense, the steam will rush in *b* nearly full of cold water; it will strive to ascend, but meeting the

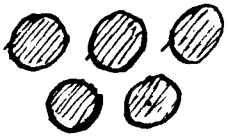


Section of part of two parallelopipeds, of their real size.

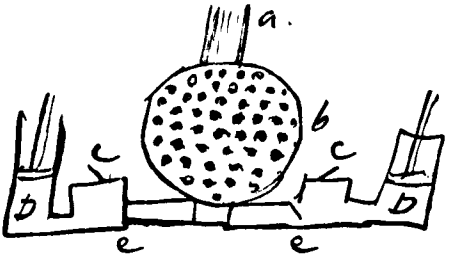
diaphragm, must go up in small particles, and can never reach the top; the piston *b* descending, the other ascends, and receives what steam remains. *b* becoming a plenum, the trigger *g* opens the back-valve and permits the water to run through the box *b* from the superior to the inferior cistern; the air produced from the water is chased out at the top valve, and the warm water at the side one. If the thinness and shortness of the middle part between the condensers should not shorten the time of condensation I propose making a small hole into it, to let water in occasionally, which can scarce fail to remedy the evil. In the last condenser I had of this kind I did not find any inconveniency from the untightness of the valves, as feared, nor from the air disengaged from the cold water, it appearing less in quantity than was apprehended. In case this condenser does not perfectly answer I am to try one I had made long ago, which, for some reasons, was laid aside, but I again think may be used; it is of the pipe kind, and has no less than 48 feet in surface, though its contents are very small. It consists, not of pipes, but of thin parallelopipeds of white iron, about this size :—

There are 25 of these parallelopipeds (they are hollow, and supported as represented, to prevent crushing): they are each 10 inches by 13½, consequently have each near two feet of surface; they are placed about half an inch asunder, through which space the water must be made to run. The whole steam of this cylinder can only heat such a condenser $\frac{1}{32}$ inch thick to 90°, which one may conclude it will do instanter. These hollow parallelopipeds communicate altogether at each end by means of other thin parallelopipeds, also properly supported. The reason why this condenser was not tried sooner was that I once imagined that there was much air mixed with steam; I therefore intended my condenser to be perfectly exhausted each time by filling it with water; now this condenser required two large pumps, and consequently was too great a burthen, but I now find little air to be mixed with steam, and I see by calculation that it will make little difference whether the condenser be filled with water or no; as its contents are but a small part of the empty space at bottom of the cylinder, even when the piston is as low as you can venture to bring it. Therefore a pipe condenser, if used, may be kept perpetually exhausted, like the receiver of the air-pump. Now, if you prefer this kind of condenser, I will give you what I think a proper form. Let a hollow cylinder be made, of what you think a proper diameter, but not exceeding a foot in length; the materials thin pinchbeck; let two ends be fitted to it; let these ends be pierced with as many

holes as they can hold, of $\frac{1}{4}$ inch diameter, and $\frac{1}{8}$ asunder, thus :—



Let these holes be pierced through both ends at once, and let very thin pipes of the same metal and of the length of the cylinder be soldered into them; these pipes being open at bottom, are to let the cold water pass through them, the steam being in the inside of the cylinder and on their outside.



a, the steam-pipe; *b*, the drum condenser; *c*, two valves, to pass air and water; *d*, the pumps; *e*, valves to prevent regress of water, &c. You need only solder the pipes and heads with tin. Remember that it requires 23 cubic inches of water, at 50°, to cool to 90° one cubic foot of steam; and that it will not be proper to allow the water to be heated above $\frac{1}{16}$ inch over the whole surface of the condenser.

I conclude this letter on the 20th, during one of my weekly headaches. Some confounded people are doing their endeavour to bring on a dispute with the Great and Monkland Canals about water, which keeps me here, much against my will, for a

few days. Compliments to all friends, and believe me ever yours.

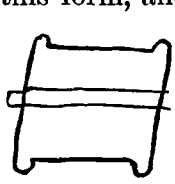
[81.] MR. WATT TO DR. ROEBUCK.

Perth, April 8th, 1770.

I got here last night late, having been detained at the ferry. I have seen nobody yet. I have had a good deal of thought about the engine, and believe things may be mended even with this condenser. I shall write again in a few days. * *

The plug-frame is to be got fitted up as soon as the patterns for the new condenser are finished and sent off. When the plug is finished complete, the cast-iron snout is to be opened, and a strict examination passed upon the regulator and its joints; (but first of all that part of the copper pipe that is without the snout is to be new painted, that it may dry while the plug is making.) The regulator and snout being judged to be tight, the boiler is to be heated, and every place where it blows steam to be made close by what John Parker calls caulking. The wooden cylinder top is then to be made tight, and cork to be put in the jack-head as directed. The condenser pump-rods need not be lengthened, for it will do no service. When all these things are done the dimensions are to be exactly taken for the new condenser, without taking down the old one, and it is to be made as far as it can be, but the old one is not to be taken down till I return. A whorle of plane-tree, as large as can be got on, is to be fixed on the axis of the condenser-crank, near the boiler end; it may be of

this form, and about 8 inches thick; a block must also be got to hang to one of the couples for the weight to go over that drives this:—and I beg the lads to be as diligent as they can, as I expect to be back before all this is done, and shall not be able to stay long.



(Indorsed, "Directions about Kinneil Engine.")

[82.] MR. WATT TO DR. ROEBUCK.

Cupar of Angus, April 15, 1770.

I wrote you from Perth on Sunday last, since which time I have been close employed viewing this country and examining which would be the proper track for the canal, which I begin to survey to-morrow. You will, perhaps, think a week a long time to look about one; but it appears possible to make a canal from the hill of Kinnoul (opposite to Perth) to Forfar, which will measure above 36 miles, and that without a lock. There is a great deal of rough ground betwixt Perth and this place, but from hence to Forfar the ground is as well adapted as may be expected in any country. This valley of Strathmore is about 18 computed miles in length and six in breadth, but not a dead flat, as we imagined; the soil in general good, and of all kinds, from sand and gravel to clay, though I have seen none so strong as the Kerse clay, and very little of the country so flat. Agriculture is more advanced here than in some more southern parts of Scotland. There are some small proprietors of land, but it mostly belongs to great

lords. There is here a great spirit of improvement; and great abundance of shell marl, but no fuel, except what is brought from Dundee over hills. As my stay may be longer than expected, you will, after the directions of my last are fulfilled, try the following experiments with the present condenser. 1st. After the engine is fairly set a-going with a good steam, and purged of air, shut the regulator against condensation; and, after working a few strokes of the condenser to clear the condenser-pipe of air, stop the operation of the pumps:—lift both the triggers of the great valves, that the condensing boxes may be both filled with water;—then suddenly pull out the injecting pin and open the regulator both at once, and observe what time the engine takes to come in, the condensing pumps being at rest. Let this operation be often repeated, that no circumstance may deceive, and let the success be recorded;—the meaning of this is to try what time she takes to come in with an injection without being freed of air. 2nd. The engine in good going, shut the regulator to condensation; let down a great deal of house-head water, which make to pass through the condensers, that they may be perfectly cooled; stop the house-head water, the lower cistern being full of quite cold water; work the condenser slowly, to purge it of air, then open the regulator, and note the effect; repeat the experiment and record. 3rdly. Let the leather of the condenser pistons be pared thinner, so that any air that could lodge there may make its escape; let a strict ex-

amination be made about any other places that may lodge air;—this may be done first, before the other two experiments. You will also continue working the engine and making any other experiments that occur, (particularly taking off a part of the counterpoise on the outside,) for two or three days. If all this and what is before ordered should be done before I can return, you had best cause the lads to help to repair and fit on the great cock on the western engine, or anything else that can be of service and will keep them busy, as I would put off demolishing the condenser to the last. I grudge confoundedly the time Mackell made me lose at Glasgow:—my experiments on this condenser might otherwise have been complete before I left it. But the Lord reward him for it in a proper manner. I beg that Mr. John or you may be as much about the engine as possible, and see that the lads be busy at something or other. I have had my health very well here, though much fatigued, and sometimes very cold with the piercing winds from the snowy Grampians that form the north side of this valley.

(Indorsed: "Account of Strathmore; Directions for Experiment on Kinneil Engine.")

END OF VOL. I.

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